

The AMSAT[®] Journal

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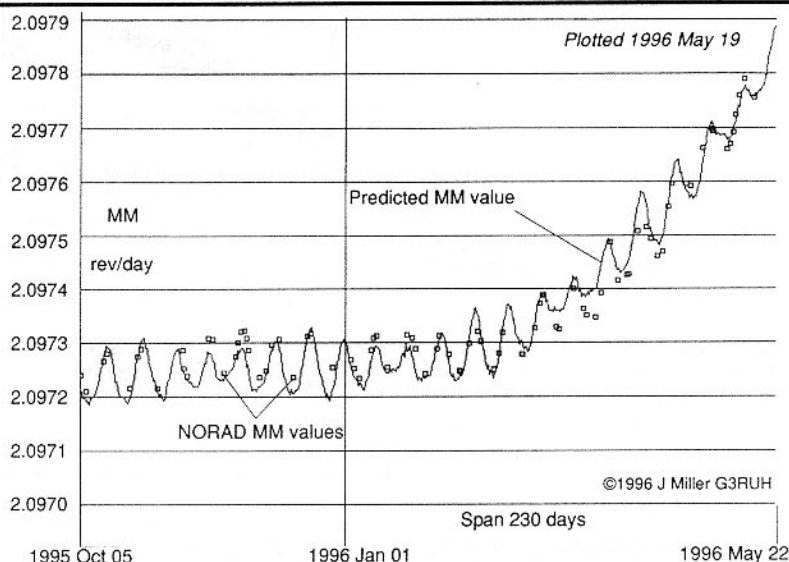


Figure 1. The predicted values of Mean Motion and other elements are based a model that includes a best estimate of the aerodynamic profile of the satellite. Forces modelled are Earth's gravity up to degree 8, zonal, tesseral and sectoral terms from the GEM10B model, Sun, Moon, drag using US Standard Atmosphere 1976 and solar radiation pressure.

From Hardware to Vaporware: AO-13 Re-Entry Plans

James Miller, G3RUH (g3ruh@amsat.org)

Without an atmosphere, AO-13 would collide with the Earth's crust on 1997 Feb 03. This is due to the pull of the Sun and Moon; the orbit eccentricity is increasing and that reduces perigee height. But the presence of Earth's atmosphere at perigee robs AO-13 of energy, which is dissipated in the form of heat. This will cause burn-up around mid-December 1996.

End-of-life effects are discernible as a) orbital period decrease and b) changes of attitude, c) heating. The first two are already observable.

Aspects of AO-13's re-entry are explored in these notes. In particular a re-orientation to the unfamiliar attitude Alon/Alat = 90/0 is proposed from mid-August 1996. This article is in two sections. The second provides a detailed numerical basis for understanding this re-entry scenario.

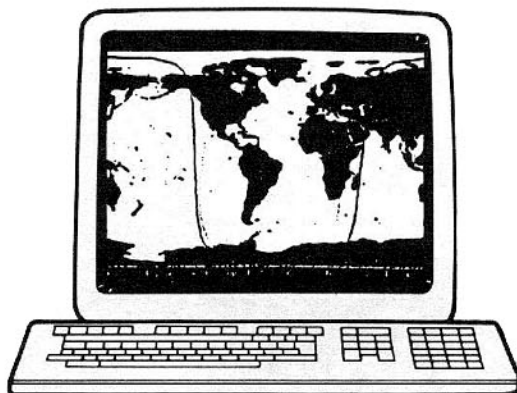
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Apogee View

A Sad Day for the Ariane 5 Project - But, Better Days are Coming

By Bill Tynan W3XO

By now, everyone has heard of the Ariane 501 Flight Test failure. Immediately following the announcement of the failure, an AMSAT News Service bulletin, jointly prepared by Dr. Karl Meinzer DJ4ZC Phase 3D Project Leader and President of AMSAT-DL and me, was issued. This bulletin expressed our sadness on hearing the news and included the following joint statement: "We, at AMSAT, have enjoyed a mutually beneficial relationship with ESA for over fifteen years, and we are, quite naturally, distressed to hear of this unfortunate occurrence. On behalf of the amateur radio satellite community, DJ4ZC and W3XO extend sincere condolences to ESA, Arianespace, CNES and the Cluster Project." Karl and I also expressed confidence that the ESA/CNES team will overcome this setback and develop a most successful launch vehicle. We concluded saying that we anticipate a successful launch of Phase 3D on a forthcoming Ariane mission. The ANS bulletin emphasized that it is too early to know what effect the Ariane 501 failure will have on the 502 schedule, or on the possible Phase 3D launch date, or the vehicle on which it will ride; but cautioned that a schedule stretched out beyond the re-entry of AO-13 cannot be ruled out.

As AMSAT members must know, the Phase 3D spacecraft is manifested on the second flight test of the Ariane 5 series (Ariane 502) which, according to ESA's schedule, established prior to the 501 test, is to take place in October of this year. Of course, only time will tell when 502 will actually be launched, or if Phase 3D will be on it. Apogee View, appearing in the March/April and May/June issues of The AMSAT Journal, addressed various eventualities that might result in a change of launch vehicles.

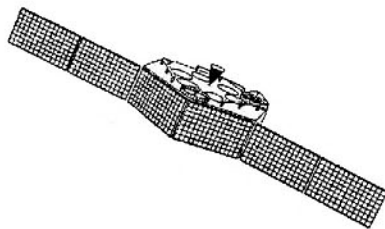
Immediately following the 501 failure, an Inquiry Board was set up to investigate the cause and report back by July 15. Not much further information is expected until after this group's report has been submitted

and reviewed by ESA/CNES officials. However, a few interesting developments have become known as of June 19 when this is being written. According to a joint ESA/CNES press release issued in Paris June 14th "a large part of the equipment contained in the vehicle equipment bay has been recovered and inspected. This has revealed the existence of a malfunction relating to the inertial platforms in Ariane-5 operating mode." The press release concluded, saying that "relevant information has been conveyed to the Inquiry Board, which will take it into account in its further deliberations".

This is good news. The mere fact that enough hardware has been recovered that the Inquiry Board can use in its investigation is reason for hoping that the group will be able to pinpoint the reason why the vehicle's gimbed nozzles went hard over, causing the rocket to veer over and suffer structural failure. The Inquiry Board is certain to examine all the pertinent hardware that can be recovered, as well as thoroughly check all software. I have been on a few such teams in my working years in missiles, and I can attest to the fact that failure investigation team members are under a great deal of pressure to do a complete job, and do it on a very tight schedule. I do not envy these individuals their task, but I am confident that they will do a credible job.

Keep tuned.

In the meantime, the best thing all of us can do is refrain from speculating as to what went wrong, how long it will take to fix it; and when, and on what vehicle, Phase 3D will be launched. At least until after the Inquiry Board reports out and the ESA/CNES officials have reviewed the findings, we won't know anything more than we do now. Speculation on our part, can only have a negative effect on the Phase 3D Project. ■



Section I - An Overview

Orbital Period

This article was written in late May 1996, seven months prior to AO-13's demise. The orbital eccentricity, presently 0.74, continues to increase slowly towards its zenith value of 0.745 in the first week of September 1996. Thereafter, drag augments the luni-solar forces, circularizing the orbit, with burn-up some three months later.

But even now, if you study the AO-13 Keplerian elements and compare mean motion for January 1996 with the mean motion for April 1996, it's increased from a value of 2.09725 rev/day to 2.09750 rev/day in just three months. This is equivalent to a reduction in period of 80 ms/orbit, and it's already noticeable how badly actual AOS and LOS times compare with predictions if you're using stale Keplerian elements. This change in period is caused by atmospheric drag at each perigee encounter (Figure 1).

Fine details of orbital period and other Keplerian elements for AO-13 have already been published [2,3,5].

Heating Effects

Heating is not yet observable as of May 1996. At 300 km altitude it's tiny, just $+0.2^{\circ}\text{C}$ extra on the solar panels. The temperature sensor resolution is 0.6°C , and radiation from the Earth at perigee warms the panels by about 9°C . Both these factors presently swamp any nuances due to friction.

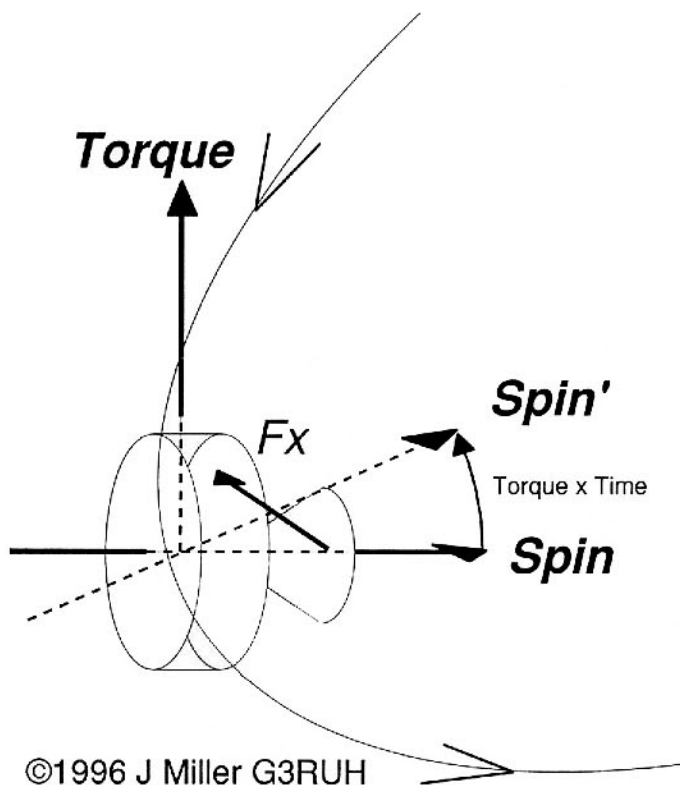


Figure 2. Windage on the motor extension causes AO-13's orientation to change.

Around September 1996 the solar panels could heat up by an additional $+5^{\circ}\text{C}$ at perigee, which will be easy to detect.

Later, in November, heating will become extreme, resulting in spacecraft failure due to damage and/or melting of antennas and solar panels.

Attitude Changes

A more subtle effect is apparent in the spacecraft's attitude. AO-13 is spin stabilized, and should unswervingly point towards the same point in space.

We can measure AO-13's orientation by several different methods. One is based on measuring the off-pointing angle of the S-band antenna using its beacon frequency modulation [4]. By doing this a few times each orbit and for a few orbits, the satellite's orientation can be determined to about 5° precision.

Now, given the satellite's orientation, one can predict the future Sun angle (the angle between Sun and solar panels). We find that predictions and measurements do not agree. They diverge by 0.1 deg/perigee. (Perigee altitude = 320 km, 1996 May).

The reason for this discrepancy is that the spacecraft's orientation is actually changing. The satellite passes through the upper atmosphere every perigee. AO-13 is not symmetric as seen sideways on. The motor sticks out, and picks up an eccentric force F_x which applies a torque (twist) to the satellite, and slews the spin axis up out of the orbit plane 0.1° every pass (Figure 2).

Clearly this can only get worse. At some point the attitude will change several degrees each perigee, and eventually precess whole revolutions at a time, effectively leaving a random re-orientation in attitude latitude after each encounter. This will render transponding useless and command very difficult.

The best solution is a final re-orientation to ALON/ALAT 90/0, plus a spin-up for additional stability some time from mid August 1996 onwards. Sun angle constraints require this be done anyway by 1996 Nov 02.

Section II - The Numbers Game

Environment in Detail

I cannot pretend yet to be an expert in the ballistics of irregular structures travelling at Mach 13 through a near vacuum. My understanding of the kinetic theory of gases, available in any physics text, provides the basis for what follows.

The numbers that characterize the drag problem are so enormous or so microscopic that they're hard to imagine. But with a little normalization we can render them in familiar terms.

Atmospheric Density

At sea level air weighs 1.2 kg/m^3 , which is comprehensible enough. The average spacing between molecules is 3.3 nm.

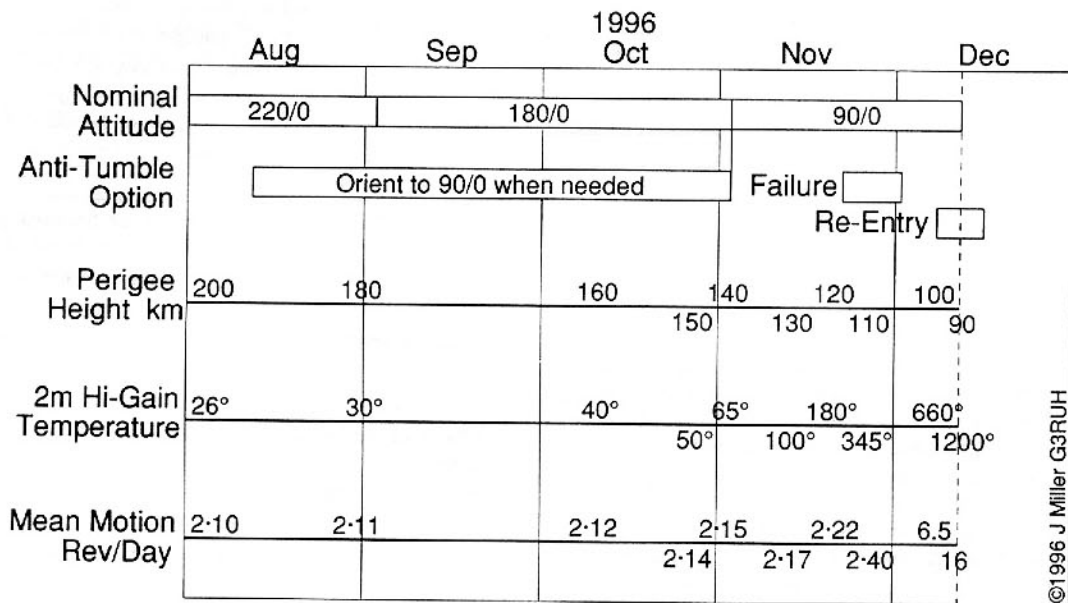


Figure 3. A summary of the final months of AO-13.

At an altitude of 100 km the mean spacing is 450 nm, about the same as the wavelength of red light or the width of a pit on a Compact Disc.

At 300 km, the atmospheric density is a mere 24 milligrams per cubic kilometer. Even at that low value, the molecules are packed at an average spacing of 13 μm , and you'd count 500×10^{12} molecules in a cubic meter. The mean free path, or average distance travelled before colliding with another molecule is however 6.6 km!

Forces

What makes these significant of course, is the colossal speed of the spacecraft. This is typically 8000 m/s, so it collides with a lot of molecules per second, and the resulting drag forces are not insignificant.

In one second, an object of area A moving at speed V ploughs through a volume of A V cubic meters, and if that's full of material

at density ρ , the object collides with $\rho A V$ kilograms of matter per second, at a speed of V. The exchange of momentum decelerates the satellite with a force of order $(\rho A V) V$. Specifically, $F = 1/2 C_d \rho A V^2$ (Newton) where C_d is a dimensionless number typically $1 \sim 2$ called the drag factor. It depends on the aerodynamic profile of the object.

Now though density is small, that value V^2 is a large number, and at 100 km altitude, an object of area 1 m^2 experiences a force of order 17 N, equivalent to a weight of 1.7 kg on Earth. Given that AO-13 has a mass of 84 kg, this is a big force, relatively speaking, especially as the perigee encounter lasts a minute or two.

To put these forces into perspective, imagine AO-13 is put into a wind tunnel on Earth. We ask, what air speed is needed to exert the same force as AO-13 experiences in space when travelling at 8000 m/s? See Table 2.

Altitude km	Mean Air Density kg/m^3	Molecular Spacing μm	Mean Free Path	Kinetic Temperature K
0	1.225	0.003	0.13 nm	288
50	5.821×10^{-4}	0.04	0.3 mm	272
100	5.297×10^{-7}	0.5	0.3 m	204
150	2.070×10^{-9}	3	78 m	635
200	2.789×10^{-10}	6	580 m	859
300	2.418×10^{-11}	13	6.6 km	973
400	3.725×10^{-12}	24	43 km	993
500	6.967×10^{-13}	41	230 km	997
1000	3.019×10^{-15}	250	53000 km	1000

Table 1. Typical properties of Earth's atmosphere. Density above 100 km varies a lot, typically 2:1 to 3:1 either way at 300 km, more at higher altitudes. The collision cross section of a molecule is taken as $3 \times 10^{-19} \text{ m}^2$. Data from Wertz [1] Appendix L3.

Perigee Altitude km	Drag Force/g	Air Speed for Equal force m/s
50	1900	170
60	1050	126
70	286	66
80	62	31
90	11	13
100	1.7	5.1
150	0.007	0.32
200	0.001	0.12

Table 2 shows the ground air speed which exerts the same force on a square meter as AO-13 experiences in space at 8000 m/s at various altitudes. $g = 9.81 \text{ m/s}^2$. For comparison, the speed of sound at sea level is 340 m/s. Blowing gently onto your hand is 0.3 m/s.

Perigee Altitude km	Normalized frictional heating	Speed for Equal Power m/s
70	16532	326
80	3591	196
90	640	110
100	100	59
110	18	33
120	4.6	21
130	1.6	11
150	0.39	9.4
200	0.053	4.8
300	0.005	2.1

Table 3 shows the heat generated by drag on a 1 m^2 object moving at 8000 m/s at various altitudes. This is normalized to 1358 W/m^2 , the Solar radiation constant. Also shown is the speed at which one expends the same amount of power overcoming drag at sea level. For example, at 100 km altitude a satellite receives 100x more heat than from the Sun alone, equivalent to the power expended towing it through the sea-level atmosphere at 59 m/s (132 mph).

Heating

The work done per second by the drag force is given by $P = FV$, which from the previous section gives $P = 1/2 C_d \rho A V^3$ watts. This power is of course expended as heat.

A satellite's chief source of heat is the Sun, which arrives at a power flux of 1358 W/m^2 . So, to gain some insight as to the scale of additional warming we can compare the frictional heating of a 1 m^2 object to the Solar radiation constant.

From another perspective, we can also ask what speed do we have to drag AO-13 through the air at sea level to expend the same amount of power. See Table 3.

Contribution	W/m^2
Incident sunlight: $1358 \times 0.31 \times \cos(20)$:	394
Reflected sunlight: $5\% \times 394$	-20
Converted to electricity: $8/0.183$	-44
Radiation from interior $T_i = 20^\circ\text{C}$ to panel:	44
Radiation to space, $T_p = 12^\circ\text{C}$:	-374
	<u>0</u>

Table 4: Solar panel radiation balance, panel at 12°C

Spacecraft Behavior

Temperature

AO-13's normal thermal environment is very benign. It operates at shirt-sleeve temperatures throughout. The solar panels maintain 12°C except during eclipses, internal temperatures are typically $15\text{--}25^\circ\text{C}$.

But what can we expect to happen when additional frictional heating as per Table 3 is apparent?

Of course, things will warm up to a temperature such that they re-radiate the extra heat. This is governed by the Stefan-Boltzmann Law which states that the radiated power from a hot body is proportional to the fourth power of the absolute temperature. The constant of proportionality is $5.67 \times 10^{-8} \text{ W/m}^2/\text{K}^4$.

Two items most vulnerable to excess heating are the solar panels and the antenna rods. If either fails, we lose our satellite.

Solar Panels

An AO-13 solar panel has an area of 0.183 m^2 , and delivers typically 8 Watts of electrical power. Since the satellite is spinning,

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half the time a panel is in darkness, and even when illuminated, sunlight falls at an angle ranging from skimming to perpendicular. In fact, the average illumination is $0.31 \times \cos(\text{Sun Angle})$ of the maximum possible. So taking a typical Sun angle of 20° , a panel receives $1358 \times 0.31 \times \cos(20) = 394 \text{ W/m}^2$ of power. A panel is designed to reflect very little incident energy, say 5% (a guess) or 20 W/m^2 . The panel radiates to space from its outside surface, but receives some radiation from the spacecraft interior. Table 4 shows the full balance sheet:

I promise that Table 4 was not *fixed*. I wrote down the power balance equation and solved it for an unknown panel temperature. It came out as 12°C , the same as shows in the spacecraft telemetry. Changing the Sun angle to 0° produces 14.5°C , also as telemetered.

Antenna Rods

The 2-meter hi-gain antenna elements stick out directly from the AO-13 body. So they cannot really *see* the warm spacecraft, only sunlight and space. They are made of thin concave tape, painted matte black. Since they are spinning, they receive only 64% ($2/\pi$) of the maximum available sunlight, and they re-radiate heat from both sides. From this we deduce these elements' temperature is given by the balance of $0.64 \times 1358 = 2 \times 5.67 \times 10^{-8} \times T^4 \text{ W/m}^2$ and so $T = 296\text{K}$ or 23°C .

The 70 cm hi-gain antenna elements are black cylindrical rods mounted on the top face of the satellite, and can see 30% warm structure and 70% space. They too receive 64% of the available sunlight, but re-radiate from $\pi \times$ more area than is exposed to the Sun. Proceeding in a similar way to the forgoing shows the 70 cm antenna rods to be at 17°C .

Frictional Heat

We can now repeat the forgoing exercises with extra heat due to drag. The results are shown in Table 5.

So for example, when perigee altitude is 180 km (1996 Aug 30), the solar panels will warm up from 12°C to 16°C , a rise of $+4^\circ\text{C}$ which should be detectable in the telemetry. Whether or not the equilibrium temperatures are actually attained depends on the duration of heating power input.

Heating Profile

Perigee heating is short lived. It builds up to a peak, and then falls away in a matter of minutes. So we need to determine this profile to see whether components will reach the equilibrium temperatures predicted in Table 5.

To do this one can seed a regular tracking program with the relevant Keplerian elements and examine the satellite's speed at (say) 10 second intervals through a perigee encounter.

Perigee Altitude km	Solar Panel °C	2m Hi Gain °C	70cm Hi Gain °C	Approx Date 1996
300	12	23	17	May 25
200	14	26	19	Aug 09
180	16	30	22	Aug 30
160	21	38	28	Oct 11
150	27	48	35	Oct 27
140	37	65	48	Nov 01
130	62	102	76	Nov 13
120	119	181	141	Nov 18
110	249	345	283	Nov 26
100	511	663	564	Dec 07
90	969	1214	1055	Dec 11
80	1638	2014	1770	—
70	2526	3078	2720	—
60	3597	4360	3865	—
50	4219	5105	4531	—

Table 5. Equilibrium temperatures of components on AO-13 due to perigee frictional drag. Solder melts at $200\text{--}240^\circ\text{C}$. Aluminium melts at 600°C and boils at 2500°C . Spacecraft moving through atmosphere sideways on. So for example, when perigee altitude is 180 km (1996 Aug 30), the solar panels will warm up from 12°C to 16°C , a rise of $+4^\circ\text{C}$ which should be detectable in the telemetry. Whether or not the equilibrium temperatures are actually attained depends on the duration of heating power input.

This can be repeated for a selection of perigee heights.

Recalling Table 3, we can say that perigee heating begins to be significant, in the sense of potentially damaging, when it exceeds 1 solar constant. That happens when perigee altitude is 135 km (1996

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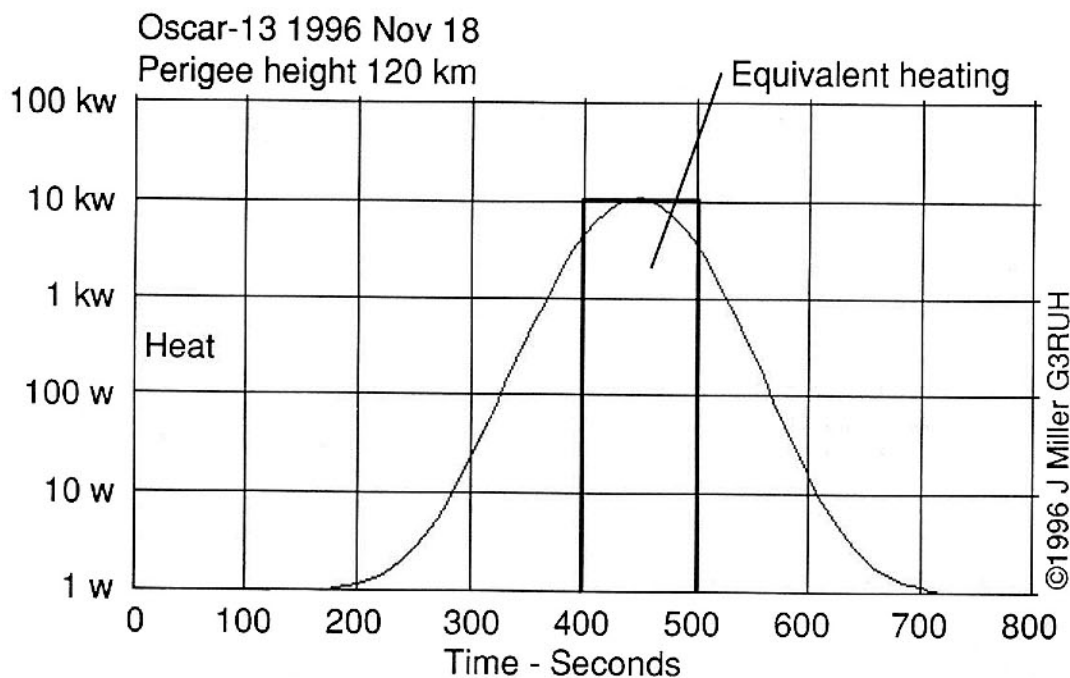


Figure 4. Heating profile for AO-13. Vertical axis is logarithmic. Equivalent heating time (Area/Peak) is 100 sec,

Nov 12) and below, and we can confine our interest to that regime. A typical heating profile is shown in Figure 4.

The total energy expended is given by the area under the power curve, and dividing this by the peak value of the curve gives an equivalent heating time as though the peak were considered rectangular in profile.

This time turns out to be between 90 and 110 seconds, and is essentially independent of perigee altitude. This is a very useful index.

100 seconds is long enough for *flimsy* parts of the spacecraft, such as the 2-meter hi-gain tape antenna, to reach the equilibrium temperatures detailed in Table 5.

Heating Dynamics

Antennas

I wrote a simulation for the differential equations of temperature for the 2-meter hi-gain tape antenna. It shows that when exposed to 10 solar constants additional heat flux (1996 Nov 24), the antenna elements reach a steady state of 260°C within 25 seconds. If heated by 100 solar constants (perigee altitude ~100 km, 1996 Dec 07) it reaches melting point after only 5 seconds exposure!

The 70cm hi-gain rods are relatively more massive. Simulation shows that exposed to an additional 10 solar constants of heat they reach 170°C after 100 seconds. However, exposed to 100 solar constants they melt after 1 minute.

Solar Panels

I do not know the failure mode of solar panels when suddenly exposed to additional heat. Presumably thermal shock will cause cells to crack.

There are six independent panels, connected via diodes to the battery charge regulator. Each panel comprises three arrays, and each array is configured as 3 x 23 cells. A cell is 14.05mm high x 21.65mm wide. The panel voltage is typically 30 - 35 volts.

There is redundancy in this construction, so that single cell failure is not catastrophic. But one suspects that once cells begin to break, a critical number of others will also break within a very short time.

Let us suppose that a temperature rise to 300°C breaks the panels. From Table 5 this should occur at a perigee altitude of ~105 km, 1996 Nov 29, assuming a sideways presentation to the atmosphere. A *bottom* presentation would obviate this problem.

Attitude Changes

Earlier it was remarked that the attitude direction is no longer stable. This is attributed to aerodynamic forces acting on the motor extension. We see a 0.1 degree/perigee increase in ALAT, and this increase is cumulative. (Perigee altitude = 320 km, 1996 May). ALAT is the angle that the motor-antenna (spin) axis points up out of the orbit plane. Its nominal value is zero so that the satellite is Earth-center pointing during the operational part of the orbit.

Whilst, 0.1 deg/perigee is minor, 1 deg/perigee would be an embarrassment. We can expect this to happen when perigee altitude is around 200 km, 1996 Aug 09, 3 months before any burn-up effects.

Final Re-orientation

The foregoing thoughts lead to some important conclusions. Towards end of life we should **NOT** keep AO-13 pointing the conventional way because from some time after mid 1996 August it will be useless as transponder and impossible to command. This is because:

- ALAT constantly cycling, end-over-end, and/or
- Exposure of the panels and antennas to great heat.

If we re-orient the satellite to ALON/ALAT=90/0 then the spacecraft presents bottom/motor to the atmosphere. This has the following benefits:

- Satellite will not re-orient as there are no unbalanced forces.
- The solar panels will be almost completely protected from direct heating.
- The top-mounted antennas are sheltered by the spacecraft body. Only the 2-meter hi-gain is exposed. The 2-meter omni, 70cm omni, most of the 70cm hi-gain, 23cm helix, and 13cm helix are protected.
- The 2-meter and 70cm omnis, which will survive longest, are correctly aligned at apogee and perigee for both transponder use and command/telemetry. The omni antennas can be ON full time
- Motor side of the satellite is the most robust. There is a temperature sensor attached to the bottom with which we can conveniently monitor heating, as was done during the original motor burns.

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5. AO-13 information is available and archived at the Internet site: <ftp://ftp.amsat.org/amsat/satinfo/ao13>. ■

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Phase 3D Mission Analysis and Command Seminar Marburg, Germany - May 10-12, 1996

Stacey E. Mills, WB4QKT (wb4qkt@amsat.org)

Command team members from world-wide Phase 3 command stations met with Phase 3D principals in Marburg, Germany for three days during the second week in May to begin finalizing the orbital parameters, IHU programming, pre-launch, launch, engineering and operational phases of the Phase 3D spacecraft. Participants of this seminar are identified in Table 1. The meeting dealt with two major topics: orbital analysis and review of command-related spacecraft systems.

Orbital Analysis

Given the upcoming re-entry of AO-13, members were well aware of the instability problems associated with highly elliptical orbits. Orbital options were considered for Phase 3D that would avoid progressively decreasing perigee due to cumulative solar and lunar forces. Because Phase 3D's major orbital axis will be considerably longer than that of AO-13, it is even more susceptible to these effects. Fortunately, much more is known about the resonances of solar and lunar effects than was the case during AO-13's orbit selection.

The details of long-term changes in highly elliptical earth orbits as a function of argument of perigee (W_p) and right ascension of the ascending node (RAAN) have been well-described by Viktor Kudielka (OE1VKW), and this discussion is available in English at: <http://asterix.nt.tuwien.ac.at/~oe1vkw/p3d-drifting>. Argument of perigee is the angle, measured in the direction and plane of satellite motion, from the ascending node to the point of perigee. Changes in W_p are best visualized as a rotation of the apogee and perigee points within a constant orbital plane (constant inclination and RAAN). For AO-13, progressive changes in W_p have resulted in movement from the initial northern apogee to its current southern location. The long-term solar/lunar effects on orbital eccentricity and perigee height depend primarily on initial W_p and, to a lesser extent RAAN. The initially proposed final W_p of 225° for Phase 3D lies close to a *resonance* point indicating maximum solar/lunar effects such that, without orbital alteration, this orbit would decay

in perigee leading to re-entry in approximately 5 years. However, if W_p is finalized at 315° , the long-term effect of an undisturbed orbit is a gradual decrease in orbital eccentricity and increase in perigee height. Although eventually reaching levels at which magnetorquing would be difficult due to the high perigee, this orbit has an indefinite lifetime. Differences in orbital coverage pattern between these two W_p values are minimal (try it on your tracking program).

After considering contingency orbits and the longest possible preservation of a functional satellite, the currently-envisioned optimal orbital approach for Phase 3D appears to be as follows:

If an Ariane 4 launcher is used, the initial orbit will be approximately: inclination (Inc) = 10° , perigee = 200 km, apogee = 36,000 km. A launch from an Ariane 5 would result in a similar orbit, with a slightly but significantly higher perigee of 500 km. If the Ariane 4 is used, an initial *safety burn* at apogee will be required within a few days to boost the perigee to a more stable (atmospheric drag free) 500 km. In this orbit, the spacecraft will be in spinning mode with solar panels retracted. Several weeks to months may be required for full system checkout, attitude determination and, perhaps, some needed precession in W_p and RAAN. The satellite is unlikely to be available for general use during this period.

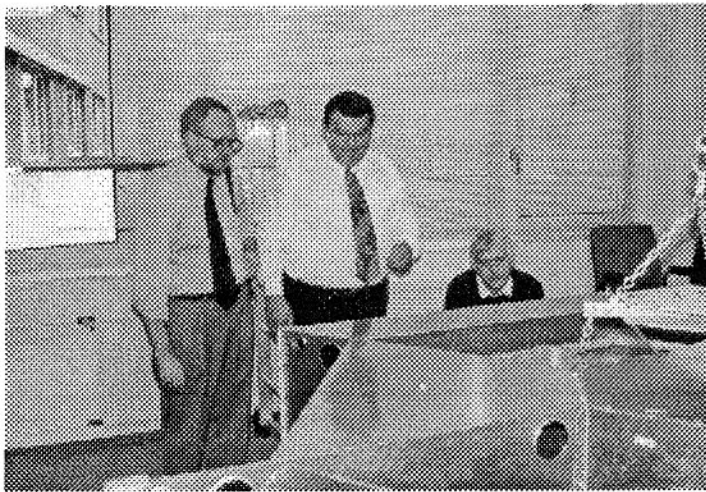
When appropriate, an additional burn at perigee will raise the apogee to its final height of 47,000 km and a second long burn will raise the orbital inclination to approximately 57° , simultaneously raising the perigee to approximately 4,000 km. At this point, most of the 400N motor fuel will have been utilized. The satellite will then be despun, the solar panels will be deployed and the 3-axis momentum wheels will be activated. Phase 3D will enter the 3-axis control phase with its antenna array pointed at the subsatellite point on the earth's surface. As soon as all systems have been evaluated, the transponders on Phase 3D will be activated for general operation (see below). At this time, the orbit will have the following approximate characteristics: Inc = $55-57^\circ$; W_p = 180° ; mean motion (MM) = 1.5 (perigee = 4,000 km, apogee = 47,000 km),

eccentricity (Ecc) = 0.677. Initial RAAN will depend on the time and day of launch. Plugging these numbers into your tracking program (with various RAAN and MA values) will help to visualize the possibilities.

In the above orbit, W_p will slowly increase with time due to torques (J_2 forces) produced by the Earth's slightly oblate shape. At this inclination, the J_2 forces slowly increase W_p and decrease RAAN. It may take up to 5.5 years for W_p to drift to the final value of 315° . During this time, the apogee of Phase 3D will move from the region of the equator into

Name	Callsign	Activities
Ian Ashley	ZL1AOX	Phase 3 Command Station / Team ZL
Jeff Garrett	ZL1BIV	Command Team ZL member
Peter Guelzow	DB2OS	Phase 3 Command Station, RUDAK, IHU, COTE
Werner Haas	DJ5KQ	Command Rx, Transponders, Transmitters
Viktor Kudielka	OE1VKW	Phase 3D Orbital Analysis Project
Karl Meinzer	DJ4ZC	Phase 3 Project Leader
James Miller	G3RUH	Phase 3 Command Station
Stacey Mills	WB4QKT	Phase 3 Command Station
Mikiyasu Nakayama	JR1SWB	Scope Camera
Graham Ratcliff	VK5AGR	Phase 3 Command Station
Dieter Zube		ATOS Project Principal

Table 1. Phase 3D Command Seminar Participants



Graham Ratcliff, VK5AGR (L), Werner Haas, DJ5KQ (C), and James Miller, G3RUH (R) examine the spare Phase 3D spaceframe at the Marburg Laboratory.

the northern hemisphere. As Wp approaches 315° , the inclination will be raised to the final 63.43° setting. This final inclination is used because at this value, Wp tends to remain constant. Some fuel may be still available in the 400N motor (even after a 4-5 year firing interval) for this procedure. If the 400N motor is unavailable for this purpose, the Arcjet motor will be used to slowly raise the inclination to the final value. Depending on the RAAN, mean anomaly (MA) can be varied by tweaking mean motion (MM) with transient apogee and perigee alterations. This will *set the clock* by placing Phase 3D's three repetitive apogees over North America, Europe, and Eastern Asia, during local evening hours. The Arcjet motor will be available for multiple years for station keeping to tweak orbital perturbations, notably rising perigee.

It is important to realize that, although the *final* orbit of Phase 3D won't be reached for up to 6 years after launch, this orbit has the advantage of indefinite lifetime due to a slow, natural rise in perigee height. In addition, 3-axis stabilization and full operational usage should be available only a few *months* after launch and the characteristics of this initial operational orbit will allow outstanding coverage of both hemispheres. In addition, the approximate MM = 1.5 orbits/day, means that Phase 3D's every other day cycle will be established at this time.

Command-Related Spacecraft Systems

Momentum Wheels

Phase 3D will have complete, 3-axis control of its orientation, based on three unique, magnetically suspended momentum (reaction) wheels located orthogonal to the Z-axis (axis through the 400N motor, analogous to AO-13 spin axis). The engineering model has been built and successfully operated. The three flight models are under construction. There is considerable commercial interest in this system, which has thus far eluded industrial designers. Phase 3D will be the first-ever satellite to use magnetically-supported momentum wheels. The wheels will be computer controlled and, because of their arrangement about the Z-axis, uniformly altering the speed of all three produces a counter-rotation about the Z-axis of up to 1-2 RPM. Differentially altering wheel speed will allow rotation in any plane. The design is such that functionality could continue with a single wheel failure.

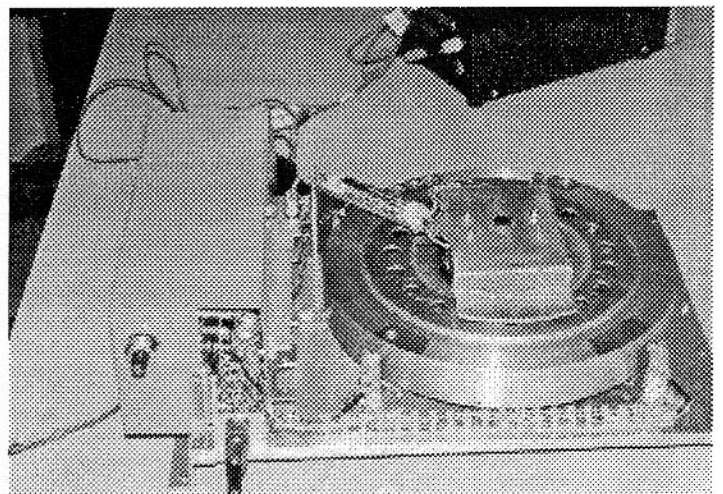
Double wheel failure would require reversion to a 3-5 RPM magnetorqued *spinner* with the solar panels extended. In normal, 3-axis function, momentum will tend to accumulate over time in the system, such that the wheels will approach their functional RPM limitation of approximately 3000 RPM. This excess momentum must be *dumped* against the external force of the activated magnetorquing system. The magnetorquing system therefore serves two functions, a backup spin stabilization system and a mechanism for momentum dumping during 3-axis stabilization. Because the Earth's magnetic field decreases with distance from the earth, there are orbital limitations with regard to the maximum perigee height for magnetorquing functionality. As with AO-13, magnetorquing on Phase 3D will take place just before, during, and just after perigee.

ArcJet (ATOS)

The Arcjet on Phase 3D is likely to be only the second such device to fly in space and the first to use ammonia as the propellant. The only other Arcjet in use employs the much more toxic hydrazine as a propellant. This system is described in more detail by Dieter Zube in the AMSAT WWW pages dealing with Phase 3D. It draws approximately 750 watts of electrical power while in use and carries 52 kg of ammonia, enough for 600 hours of operation, which is considered to be sufficient for approximately 4-10 years of *station keeping* operation, depending on the amount of its use for final inclination adjustment. Output force is approximately 100 mN. The working model has been tested for over 1000 hours. Most burns will be of approximately one hour in duration. Both the main and auxiliary batteries will be required during these burns and transponder shut down for the duration of the burn also seems likely. As with the momentum wheels, commercial manufacturers are actively following the development and utilization of this component.

Sensors

Phase 3D will employ end-mounted solar sensors just like those used in AO-13 for use during the spin phase. Solar angle in this system is measured based on the spin rate and time interval for the differential triggering of two solar sensors located behind angled



Seminar participants were given a demonstration of the Phase 3D momentum wheel engineering model which worked perfectly. Unfortunately the this figure does not reveal the wheels spinning in this strobed photograph.

slits. An end-mounted earth sensor analogous to the one used on AO-13 will also be used during the spin phase. Attitude determination and adjustment during this phase will be in an *open loop* fashion based on command station input as with AO-13. A digital two-axis solar sensor will be used during the stationary 3-axis mode, coupled with a second earth sensor pointed towards the earth along the Z-axis. In addition, as with AO-13, analog *gross* sun sensors will also be available. The software to integrate sensor information in a *closed loop* fashion with momentum wheel control is under development. The degree to which this system will be autonomous versus requiring *manual* command station attitude determination and adjustment is under study. The momentum wheels are capable of maintaining a *zero torque*, constant RPM setting. Given a stable orbit, it will be possible to implement an MA-based torquing algorithm to keep Phase 3D's antennas always pointed at the Earth's center (subsattellite point).

Transponders

Due to its 10.7 MHz IF matrix, Phase 3D has the capability of multiple merged or distinct uplinks and downlinks. In the merged mode, two uplink bands may be transponded to the same downlink, one uplink may be transponded to multiple downlinks, etc. In the *distinct* mode, each uplink has a dedicated downlink frequency. The latter setup maximizes bandwidth, while the former maximizes flexibility. Frequency combinations are limited by power budget and the obvious requirement for only one uplink or downlink per band. This flexibility will necessitate a new abbreviation system to replace the old single letter Mode designator. The baseline mode

for Phase 3D will be a 1.2 GHz (23 cm) uplink with an S-band downlink (Mode LS). This is dictated in part by the redundant receivers on the dedicated 1.2 GHz uplink and the high efficiency of the S-band transmitter and low noise for ground stations at S band. However, it is anticipated that a substantial portion of the orbit will also include old Mode-B (Mode-UV) or old Mode-J (Mode VU) operation. Old Mode-L (Mode LU) is also possible, as are multiple other combinations. In addition, higher frequency uplinks and downlinks will be available intermittently at first, on *Experimenter's Days*. Due to extremes of Doppler shift, these microwave links will be used primarily around apogee. Determination of specific transponder schedules must await checkout of the orbiting Phase 3D spacecraft, evaluation of the in-flight power requirements of each transponder, other system power demands, and power availability. The initial operating schedule will be implemented only after approval or modification by the Phase 3D Program Council.

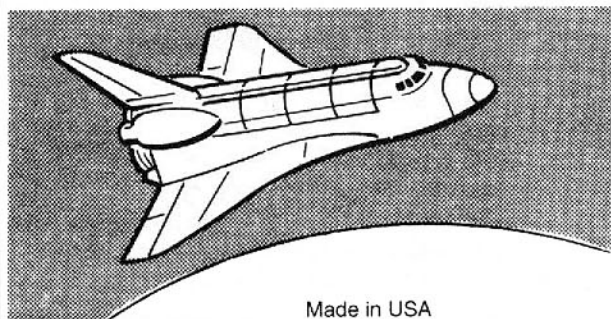
LEILA

This automatic *notch filter* has been described in detail before (see *The AMSAT Journal*, March/April 1995). It will allow for the automatic *notch out* of unacceptably high uplink signals. Although originally conceived as a series of LEILA filters, one for each uplink receiver, the current version employs a single LEILA which may be switched to any uplink frequency. In fact, given the solid state switching employed, LEILA could be continuously switched between multiple uplinks, giving the appearance of being simultaneously present on multiple uplink bands.

Beacons/Telemetry

The telemetry requirements for Phase 3D are substantially more complex than those of AO-13. The analog telemetry channels will be increased from 64 to 128 and the digital Syspage channels will be increased as well. Requirements for monitoring the momentum wheels, Arcjet motor, transponders, antenna arrays, solar and earth sensors, determining attitude, and adjusting all of the above will be well beyond those of previous *spinner* spacecraft. Accordingly, Phase 3D will output a differently organized 400 baud PSK telemetry format from its two beacons. Data will remain in the current 512 byte + 2 byte CRCC packets and existing AO-13 style modems will be fully functional. However, multiple real time data blocks, rather than a single Q-block, will be transmitted, as well as logged *Event* blocks. New software must be implemented to decode, store, and optimally display this much larger database. Details of the telemetry channel allocation and block format for Phase 3D will be published as soon as these are finalized. Given the markedly increased telemetry requirements, and the availability of RUDAK bulletin boards, as

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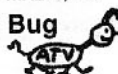
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well as widely disseminated information from *The AMSAT Journal*, WWW, and other sources, it is not anticipated that RTTY or CW components will be available on the beacon downlinks. Multiple message blocks (up to seven) will be included on the beacons and transmitted in 400 baud PSK, as is currently done with the four K,L,M,N blocks on AO-13.

GPS / RUDAK

The function of the GPS system in Phase 3D remains to be completely clarified. It is not mission critical for attitude control, and will require little command station interaction. It may be employed early in the mission for ranging and initial orbital determinations, as well as for *real-time* Keplerian element production. Its possible function in *closed loop* attitude determination and adjustment is under study. The RUDAK system is progressing and will employ two V53 CPUs rather than the initially suggested V53/i386EX combination. Control of RUDAK will require little, if any, command station interaction. Programming and normal reset functions will be handled by a separate Phase 3D RUDAK team, outside of the Phase 3D command station structure. This is fortunate, given the increasing command functions necessitated by Phase 3D's complexity. If necessary, the command IHU uplink may be used to *hard reset* (power off/on) the RUDAK, but this is not anticipated to be required.

Conclusion

In addition to the above, there were detailed discussions regarding new required command functions, needed alterations in command structure, and command failure analysis. These talks were geared for the maximization of system redundancy and avoidance of mission-critical single-point failures. The overall goal is the production of a functional, commandable satellite for a decade or more of service to the world-wide amateur community. ■

Houston AMSAT Net on Satellite

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SETI League Launches *Project Argus*

Amid great fanfare, the non-profit, membership-supported SETI League kicked off its long awaited *Project Argus* survey of the heavens for microwave signals of possible intelligent extra-terrestrial origin. At 1900 UTC on Earth Day, April 21, 1996 the first five radio telescopes in the Argus effort went on line simultaneously in Spain, Toronto, Colorado, Hawaii, and SETI League headquarters in New Jersey. The simultaneous *launch* of these five stations was coordinated by HF radio by participating Amateur Radio operators.

"This small step for humanity," commented SETI League President executive director Dr. H. Paul Shuch, N6TX, "represents a humble beginning for what will ultimately be a global effort. From five stations today, we can foresee 500 participants within two years, and perhaps five thousand by the year 2001. When we reach that level, there will be no direction in the sky which evades our gaze. Then we can hope to find the answer to a fundamental question which has haunted us since we first recognized that the points of light in the night sky are other suns: *Are we alone?*"

Traditional research-grade radiotelescopes can view only a fraction of the sky at a given time, typically, on the order of one part in a million. All-sky coverage with these instruments would thus require a million telescopes, each at a cost of tens of millions of dollars. Project Argus employs a large number of much smaller, quite inexpensive Amateur Radiotelescopes, built and operated by Amateur Radio experimenters at their individual expense. The equipment, although of modest sensitivity, is capable of detecting microwave radiation from technologically advanced civilizations out to a distance of several hundred light years. There are hundreds of sun-like stars within that distance, many of which are believed to harbor their own planetary systems. (via *SearchLites* the Quarterly Newsletter of the SETI League, Inc.)

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OSCAR Satellite Communications Achievement Award: Make one satellite contact with 20 different U.S., Canadian call areas or DXCC countries.

OSCAR Sexagesimal Award: Make one satellite contact with 60 different U.S. or Canadian call areas or DXCC countries. (Can include the above 20 contacts from *Oscar Satellite Communications Achievement Award*.)

OSCAR Century Award: Make one satellite contact with 100 different U.S. or Canadian call areas or DXCC countries. (Can include the above 60 contacts from *Oscar Sexagesimal Award*.)

South Africa AMSAT Satellite Communications Achievement Award: Make 25 satellite contacts on any Phase II satellite (low earth orbit, ie: FO-20, AO-21, AO-27, RS-10, RS-12, RS-15).

Additional Satellite Awards: Additional details on the following awards may be obtained by requesting an awards application from ARRL Headquarters, 203-666-1541.

Worked All Continents Award (WAC): One satellite contact with any station on each of the eight continents.

DXCC Award with Satellite Endorsement: One satellite contact with any station in 100 different DXCC countries.

Worked All States Award: One satellite contact with any station in each of the fifty states.

VHF/UHF Society Century Club Award: One satellite contact with any station in 100 different grid squares. Endorsements for each 25 squares.

Recent awards (Mid-1993 - March 1996):

OSCAR Satellite Communications Achievement Award:

No.	Callsign	Date	No.	Callsign	Date
252	WA8NPX	09SEP93	274	K4FPF	28OCT94
253	N0ULV	21SEP93	275	VE3EFF	28OCT94
254	IW1PED	07OCT93	276	WB6LLO	11NOV94
255	VE7KLX	24OCT93	277	WA5TWT	22NOV94
256	KB5ZRV	24OCT93	278	HH2B	22NOV94
257	N8VEA	13NOV93	279	KB4NVD	10DEC94
258	KB2DAB	13NOV93	280	N8WLJ	10DEC94
259	WA8JOI	13NOV93	281	F1OK	03JAN95
260	WA7GCS	04JAN94	282	W4LMJ	03JAN95
261	XE1KK	04JAN94	283	N1KAT	22JAN95
262	W3BBO	04JAN94	284	K8RWL	22JAN95
263	VP9MU	05JAN94	285	N0FXC	22JAN95
264	KF9KF	07JAN94	286	N2QXF	26APR95
265	WB5OTD	03APR94	287	SV1CIF	15MAY95
266	KB4IUL	02MAY94	288	WB4SON	14JUL95
267	WB8OTH	30MAY94	290	N3JNX	14JUL95
268	WB5NRI	25JUL94	291	KS4DU	18NOV95
269	KA0YOS	25JUL94	292	VE6ITV	18NOV95
270	N2MUC	26JUL94	293	N8JTR	20JAN96
271	N0GVK	29AUG94	294	N5YAV	19MAR96
272	ZL2UYH	18SEP94	295	HB9SLO	19MAR96
273	KG8BG	19SEP94			

OSCAR Sexagesimal Award:

No.	Callsign	Date	No.	Callsign	Date
92	PY2ACM	28MAY93	101	WB8OTH	30MAY94
93	WA3YGQ	28MAY93	102	KB4IUL	25JUL94
94	WA8NPX	09OCT93	103	KA0YOS	18SEP94
95	IW1PED	09OCT93	104	KG8BG	11NOV94
96	WA8JOI	13NOV93	105	WB6LLO	11NOV94
97	KB5ZRV	21FEB94	106	VE3EFF	15MAY94
98	WB5OTD	03APR94	107	K4FPF	14JUL95
99	N8VEA	05APR94	108	SP5FKW	15NOV95
100	VP9MU	26APR94			

OSCAR Century Awards:

No.	Callsign	Date	No.	Callsign	Date
01	G3IOR	14FEB77	02	WA2CBB	08APR77

03	W2RS	21APR77	13	G6XHR	12SEP88
04	VE3BNO	21JUL78	14	K8XF	10SEP90
05	W4AIT	31JUL78	15	WA5ZIB	12AUG92
06	W1JR	31JUL78	16	VE4AMU	10NOV92
07	K2ZRO	11JUL80	17	PY2ACM	28MAY93
08	OK3AU	25FEB81	18	WA8JOI	13NOV93
09	?????		19	WB8OTH	30MAY94
10	W9MXC	22DEC83	20	WA3YGQ	25JUL94
11	W0SL	30MAY84	21	KB5ZRV	11NOV94
12	WH6AMX	30MAY84	22	SP5FKW	20JAN96

South Africa AMSAT Satellite Communications Achievement Award:

No.	Callsign	Date	No.	Callsign	Date
12	N3KQV	25JUL93	25	VE3EFF	28OCT94
13	W5UB	25JUL93	26	KG8BG	30OCT94
14	VE2Q	25JUL93	27	KC4YAU	11NOV94
15	WS7C	25JUL93	28	KB4NVD	10DEC94
16	IWIPED	07OCT93	29	NH6YK	03JAN95
17	KB5ZRV	24OCT93	30	W4LMJ	03JAN95
18	N8VEA	13NOV93	31	K8RWL	22JAN95
19	WA7GCS	04JAN94	32	XE1KK	22JAN95
20	WB5OTD	03APR94	33	N2QXF	14JUL95
21	WB8OTH	30MAY94	34	F1OK	14JUL95
22	KA0YOS	25JUL94	35	N7DQU	29SEP95
23	N2MUC	26JUL94	36	HR2KOS	15NOV95
24	N0GVK	29AUG94			

JAS-2 Launch Date Set

Fujio Yamashita, JS1UKR, of the JARL Technical Laboratory recently informed us that the launch of JAS-2 is set for August 17, 1996. JAS-2 is now scheduled to be launched along with ADEOS, **AD**vanced **E**arth **O**bservation **S**atellite, within a launch window between 0129 and 0154 UTC. If the launch is postponed, the launch window should be same time each day in order for ADEOS to obtain a suitable orbit. The launch window will open from August 17 and close on September 30, 1996. The following provides the initial mission sequence for JAS-2 aboard the fourth launch of the H-2 rocket:

Seconds Event

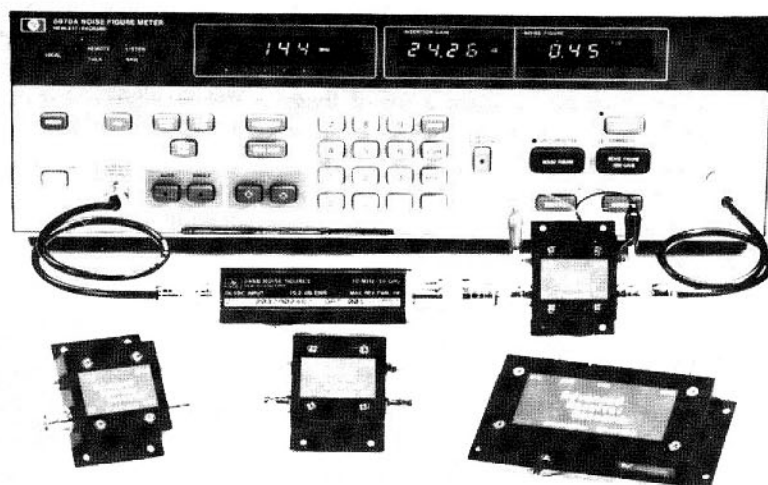
0	Lift-off
93	SRB burn-out
100	Separation of SRBs
230	Separation of faring
354	First stage engine cut-off
355	Separation of the first stage
361	Ignition of the second stage engine
900	Second stage engine cut-off
947	Orbital injection of ADEOS
	second engine re-ignition
2273	orbital injection of JAS-2 (JAS-2 is inactive while on the H2. JAS-2 activation will occur at separation over Antarctica where 8J1RL at Syowa Base will try to be first to acquire JAS-2's beacon on 435.795 MHz.)

After separation and orbital injection of ADEOS, a second re-ignition of the engine will attempt to raise JAS-2's apogee to 1700 km. During this engine re-ignition, residual propellant should provide an *idle burn* meaning supplied fuel is in a gaseous and not liquid state. As a result, thrust force will be less than normal during this burn. For up-to-date JAS-2 information refer to the JARL Home Page: <http://www.jarl.or.jp/jarl/jas-2/>

Starting November 15, 1995, we started numbering from US1 here with Mike Scarcella's signature instead of Andre Botes:

No.	Callsign	Date	No.	Callsign	Date
US1	SP5FKW	15NOV95	US6	AA4XO	20JAN96
US2	SV1SN	18NOV95	US7	N8JTR	20JAN96
US3	KS4DU	18NOV95	US8	DL6UAA	20JAN96
US4	VE6ITV	18NOV95			

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P50VD	50-54	< 1.3	15	0	DGFET	\$29.95
P50VDG	50-54	< 0.5	24	+12	GaAsFET	\$79.95
P144VD	144-148	< 1.5	15	0	DGFET	\$37.95
P144VDA	144-148	< 1.0	15	0	DGFET	\$37.95
P144VDG	144-148	< 0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	< 1.8	15	0	DGFET	\$29.95
P220VDG	220-225	< 1.2	15	0	DGFET	\$37.95
P220VDG	220-225	< 0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	< 1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	< 1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	< 0.5	16	+12	GaAsFET	\$79.95

Inline (rf switched)	Freq. Range (MHz)	N.F. (dB)	Gain (dB)	1 dB Comp. (dBm)	Device Type	Price
SP28VD	28-30	< 1.2	15	0	DGFET	\$59.95
SP50VD	50-54	< 1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	< 0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	< 1.6	15	0	DGFET	\$59.95
SP144VDA	144-148	< 1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	< 0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	< 1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	< 1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	< 0.55	20	+12	GaAsFET	\$109.95
SP432VD	420-450	< 1.9	15	-20	Bipolar	\$62.95
SP432VDA	420-450	< 1.2	17	-20	Bipolar	\$79.95
SP432VDG	420-450	< 0.55	16	+12	GaAsFET	\$109.95

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The Inexpensive OSCAR Station

David Reinhart, WA6ILT

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WA6ILT@K1UGM.#EMA.MA.NA

This article developed from a thread in late March about the high cost of setting up an OSCAR station on the *AMSAT-BB* mailing list. Many writers were concerned about the seemingly endless outlays for new equipment every time a new satellite goes up, whether it is a new digital bird with a different modulation scheme or a bird like Phase 3D which will push us toward the microwaves.

Quite honestly, I share a lot of these concerns, but I think many Radio Amateurs are approaching OSCAR work (and Amateur Radio in general) with a mind-set that is both common in our culture and destructive. Let me enlarge on that with some personal history.

I have been a Radio Amateur for almost thirty years. Up until October 1994, my on the air activity had been limited to HF (SSB, CW & RTTY) and 2-meter FM. At that time, I started working RS-10 with a very unspectacular station. The downlink

receiver was my TS-440S with an Advanced Receiver Research DGFET preamp. My uplink radio was an old Kenwood multimode (borrowed from a friend in my radio club) and an MFJ three element beam. I used an old Alliance U-110 I had lying around to control antenna azimuth. Total expense to get on the air was a mere \$50!

Getting *on the birds* was extremely exciting, but one thing I made myself do was go slow. I did not rush out and buy a new multiband/multimode rig, new antennas, etc. I watched the advertisements on packet, in Ham Trader and other places, looking for good bargains on used gear. Meanwhile, I was tucking away some money toward eventual purchases.

Today, my station consists of an Icom 271H/471H pair with the internal AC supplies and computer interfaces. They came with Icom 2-meter and 70 cm preamps; not the best, but workable. I got that whole package for \$1,200. I did not

need to buy another hefty DC supply or external amplifiers, a savings of both space and money. The antenna farm is a Cushcraft AOP-1 that I got (along with an ARR 2-meter switched preamp) for \$100. Yes, the 70 cm SWR goes crazy when it rains, but in general it works fine.

My azimuth rotator is a rebuilt HD-73, and I found a used Yaesu G500 elevation rotator that looked like it had never been used at Burghardt Amateur for about two-thirds of the new price. I sold the ARR preamp when I bought the Icom rigs, and I used the U-110 for elevation until I found the deal on the G500.

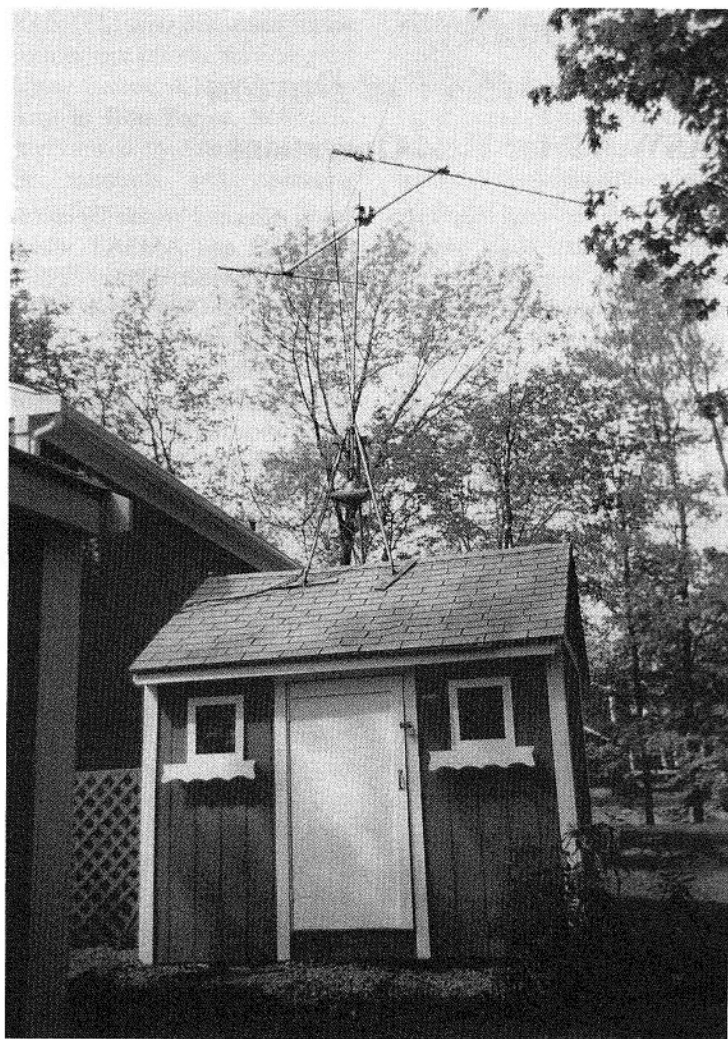
The antennas are mounted on a tripod that held a small HF beam at my old QTH. The whole collection sits on a garden shed in my back yard. From Northwest to Northeast, at low elevations, I have to shoot through the roof of the house when the bird is low, and I cannot turn the beam through South without raising it above 45 degrees because of a low tree branch (Figure 1).



David Reinhart, WA6ILT has innovatively put together an inexpensive satellite station.

What's missing? I do not have automatic tracking and tuning gear. Who knows why, but I do not seem to have as much trouble juggling mike/key, rotators and tuning as some people. A tracker-tuner is a *wish list* item. I could work the digital birds, since I have an AEA DSP-2232, again used. It cost me less than two-thirds list price. But I am having too much fun on the analog birds just now to jump into the digital modes.

It's also important to note what I won't skimp on. My coax is the lowest loss stuff I could find at the time with the best silver/Teflon connectors with everything very



The author's 2-meter/70cm antenna set-up.

carefully sealed. My next door neighbor has an uncle who is a Radio Amateur and he commented on how much care I put into erecting that antenna.

If I couldn't hear myself and other stations better than they report they can hear me, I would have already bought a new 2-meter preamp. A new 70cm preamp is at the top of my *watch for list*.

The gist of all this is that ham radio activity is an additive thing. I'm still using some stuff that I bought 29 years ago. Pick up Item A when you find a good deal, and do not rush out and buy Item B just because you found Item A. If you can avoid the all too frequent addiction to instant gratification that permeates our society, you can save a lot of money. I have tried to home-brew some stuff, but I'm just not a very good builder, no matter how hard I try.

Yes, I am worried about handling the move to microwaves. It's going to be tough getting sufficient RF out at a reasonable price. I am concerned about an antenna pointing system that is both rugged enough and accurate enough to point multiple, high-gain antennas. I can live with down converters for receive, and I may even try building one (glutton for punishment that I am).

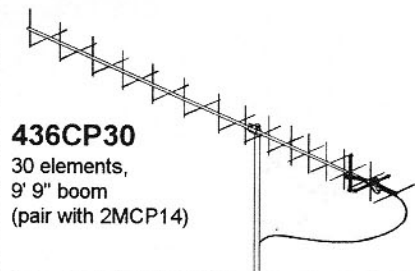
I do not plan to be on the leading edge of the new modes. I'll get there, but I don't expect to be on 10GHz the day that Phase 3D opens for business. If everything goes well with the launch, that satellite will be in orbit for years. In conclusion, let's just say that the attitude you approach satellite work with can make a lot of difference in how much you get out of it. ■

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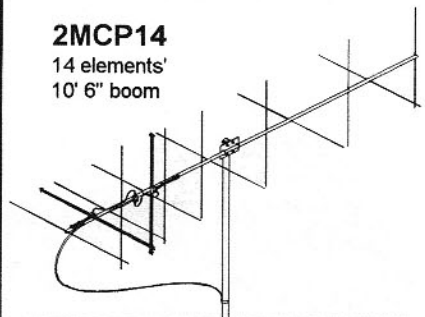
NEW!
Ultra-gain!



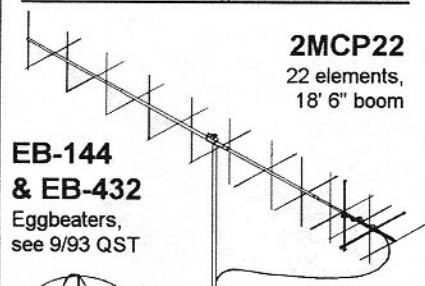
436CP42-U/G
42 elements,
18' 10" tapered boom
(pair with 2MCP22)



436CP30
30 elements,
9' 9" boom
(pair with 2MCP14)

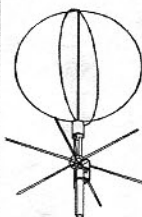


2MCP14
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10' 6" boom



2MCP22
22 elements,
18' 6" boom

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Field Ops Update: *Another Great Year for AMSAT at Dayton*

Barry Baines, WD4ASW, VP for Field Operations

AMSAT enjoyed another outstanding and successful outing at the Dayton Hamvention. The weekend was marked by a number of achievements including:

- Bill Tynan, W3XO, AMSAT President, receiving the *Ham of the Year Award* from the Dayton Hamvention.
- Giving two AMSAT Forums, both at the Hara Arena (Some others were given offsite).
- Conducting a stellar volume of activities at the AMSAT booth.
- AMSAT members enjoying a wonderful evening at the Amber Rose Restaurant (Next year's dinner will be at the same site).
- A number of foreign satellite enthusiasts visiting the AMSAT booth;
- AMSAT and Keith Baker, KB1SF, AMSAT Vice President, being featured in the lead article on the Hamvention in the Saturday, May 18, edition of the *Dayton Daily News*.
- A new group of members stepping forward to help man the AMSAT booth.

The Dayton Hamvention weekend was shifted from April 26-28 to May 17-19 in an attempt to find better weather. The plan

was very successful—after some light rain on Friday morning, there was picture perfect weather for the remainder of the Hamvention. The good weather allowed the flea market to attract a number of attendees, which allowed the indoor exhibit areas to not be as crowded. About 30,000 people purchased tickets; slightly down from the previous year but still a very impressive showing.

The AMSAT booth was located in its traditional area—booths 445-448 in the Ball Arena of Hara Arena. An enthusiastic crew of more than 20 volunteers helped construct and man the booth. A number of volunteers had stepped forward to help after posting a *Help Wanted* announcement on *amsat-bb*. Work assignments were made prior to the Hamvention and members worked the booth during shifts. Volunteers came from all over North America (12 states plus Canada's Northwest Territories) as well as Masaji Tamagawa, JH1AOY, a JAMSAT member who assisted with booth setup and takedown.

AMSAT featured several new twists at the booth this year. Terry Douds, WB8CK1, created several video tapes based upon the

Sci-Fi Channel *Inside Space* segment on Phase 3D and AMSAT which provided closed loop video display of the Integration Lab and a QSO on AO-27. Terry installed the appropriate video equipment for the display. Terry also provided a computer and monitor for demonstrating WISP and other windows software. New T-shirts and polo shirts sporting a blue patch and artwork were a hit as well as a new ballcap. New decals and patches (including a new SAREX patch) were also available. Phil Chien, KC4YER, designed a number of large photo displays featuring Phase 3D; the materials were carried to Dayton by Lou McFadin, W5DID, and put together with the help of Stan Wood, WA4NFY. A rebuilt Phase 3D model featured a modification which simulates the deployment of its solar panels.

Despite the lack of new publications and software at Dayton, we still experienced a very high level of activity at the booth, with total receipts very close to previous year's levels. This included a large number of memberships. An incentive for joining (or renewing) included a free copy of KB1SF's *How to Use the Amateur Radio Satellites*, a laminated satellite frequency chart, and additional handouts. These handouts included a six page *Sources of Information About the Amateur Satellite Program* developed by Gary Rogers, WA4YMZ. This handout has listings of satellite books and periodicals, E-mail, FTP, and World Wide Web Resources, and miscellaneous listings of various AMSAT software. In addition, an updated *Area Coordinators Listing* which was given to all new members.

The first AMSAT Forum was conducted one hour after opening of the commercial exhibits on Friday afternoon. The forum was moderated by Keith Pugh, W5IU, AMSAT VP-Operations, and included both a SAREX overview and a Beginner's Forum. Frank Bauer, KA3HDO, VP for Manned Space Programs, served as the leader of the SAREX portion and included presentations by Rosalie White, WA1STO (last year's Dayton's *Ham of the Year*) on the educational aspects of SAREX, and Matt



The Dayton Hamvention banquet drew AMSAT members from near and far. Here, Stan Wood, AMSAT-NA Asst. VP, Engineering, WA4NFY (L), and Miki Nakayama, JR1SWB, from JAMSAT (R) share a moment with Michelle Ervin, KA9FUL, a Director and Treasurer for the 1996 Dayton Hamvention. Michelle also recently became a new member of AMSAT-NA. (AMSAT-NA photo by Keith Baker, KB1SF)

Bordelon, KC5BTL, who discussed future SAREX development efforts including the upcoming Space Station. A highlight was a phone hookup to Ron Parise, WA4SIR, who was interviewed by Frank about his two shuttle missions and operating Amateur Radio from space.

The Beginner's Forum presented a brief overview of amateur satellites and how they are used, and then concentrated on discussing where to get information and advice on building satellite stations. Emphasis was placed on using AMSAT's Area Coordinators as resources and using Gary Roger's article as a starting point for researching information (see article elsewhere in this issue). Both the Resource Listing and Area Coordinator Listing handouts were also given to the attendees of the Beginner's Forum.

On Friday evening, nearly 70 AMSAT members attended the dinner at the Amber Rose Restaurant, which was enjoying its grand reopening that weekend. Newly remodeled, the facility was well suited for our gathering, with excellent food at very reasonable prices. Gerd Schrick, WB8IFM, and Ed Collins, N8NUY coordinated the logistics. Following dinner, several brief presentations were made, including one by Frank Bauer to Graham Ratcliff, VK5AGR who has served on the SAREX Working Group for many years. Frank, a NASA manager, gave Graham the appropriate NASA wear.

Saturday was *The DAY* for Dayton, with the flea market open at 0600 and the commercial area open at 0800. AMSAT made an immediate splash as both AMSAT and Keith Baker, KB1SF, were highlighted in the Dayton Daily News in a color spread about the Hamvention. The reporter who wrote the story was amazed to learn of the amateur satellite program; to have a local involved only added to the news worthiness of the feature (Keith lives in Xenia). Reading about AMSAT in the local paper while having breakfast at the Bob Evans restaurant near the hotel prior to proceeding to the Hamvention was a great way to start the day!

The Booth was very busy by mid-morning. The second AMSAT Forum, on Phase 3D, was from 1300-1500 and standing room only with Lou McFadin, W5DID, Stan Wood, WA4NFY, Keith Baker, KB1SF, Graham Ratcliff,

VK5AGR, and Bill Tynan, W3XO, leading the presentations and discussions. Following their material, Ed Krome, KA9LNV, made a well received presentation on how to construct a satellite station for Phase 3D. Ed is the author of *Mode S: The Book* and is well qualified to provide pointers on constructing a station for the various microwave bands that Phase 3D will sport.

Saturday evening's sold-out Hamvention Banquet had a space science orientation. Our own Bill Tynan, W3XO, received the Hamvention's highest honor, *Ham of the Year* for his many years of contributions to the VHF/UHF aspects of our hobby as well as the leadership he has provided to AMSAT. The banquet speaker was AMSAT member Dr. Paul Shuch, N6TX, Executive Director of the Search for Extra Terrestrial Intelligence (SETI) League.

Once again, AMSAT made a significant impact on the Dayton Hamvention. Many thanks to the dedicated, hard-working individuals who helped to make our efforts such a success by volunteering to construct and man our exhibits, answering the myriad of questions concerning satellites in general, and soliciting support through memberships and handling of AMSAT materials. Along with the vast amount of energy expended and lack of sleep, we all had a lot of fun throughout the weekend and the spirit of cooperation and teamwork made the effort that much more enjoyable. Thanks!

Remember, the 1997 Dayton Hamvention is only 10 months away (May 16-18, 1997), so start making your plans to attend! ■

Life Members living outside the United States can receive *The AMSAT Journal* via Air Mail by remitting \$15 U.S. per year.



AMSAT-NA VP for Manned Space, Frank Bauer, KA3HDO (L), presents a NASA shirt and cap to Graham Ratcliff, VK5AGR, at the Friday evening AMSAT dinner. Frank expressed both AMSAT's and NASA's gratitude for Graham's strong support from down under as a key ground station for the Shuttle Amateur Radio Experiment. (AMSAT-NA photo by Keith Baker, KB1SF)



Ed Krome, KA9LNV, author of AMSAT's *Mode S-The Book*, presents his ever-popular program on innovative ways to construct microwave ground stations to an enthusiastic crowd during the Phase 3D forum at the 1996 Dayton Hamvention. (AMSAT-NA photo by Keith Baker, KB1SF)



AMSAT-NA President Bill Tynan, W3XO, proudly displays his *Amateur of the Year* award for the over 100 guests at the 1996 Dayton Hamvention banquet in Dayton, Ohio. Bill's remarks encouraged those present to continue their quest for opening up new frontiers by the way of Amateur Radio. (AMSAT-NA photo by Keith Baker, KB1SF)

Dayton Volunteers

Many thanks to the following members who volunteered a portion of their time at Dayton to help make AMSAT one of the best looking and most informative exhibit areas at the Hamvention:

Keith Baker, KB1SF Xenia, OH
 Steve Bible, N7HPR, Kingsland, GA
 Dan Bledsoe, WB6LYI, Long Beach, CA
 John Boudreau, VE8EV, Inuvik, NT
 Kermit Carlson, W9XA, Batavia, IL
 Bob Carpenter, W3OTC, Rockville, MD
 Terry Douds, WB8CKI, Lancaster, OH
 John Hansen, WA0PTV, Fredonia, NY
 Bruce Howes, KB2VKJ, East Amherst, NY
 James Kelly, KK3K, Philadelphia, PA
 Pat Kilroy, WD8LAQ, Bowie, MD
 John Klim, N3KHK, Beltsville, MD
 Ron Long, W8GUS, Columbus, OH
 Jerry Malin, WB2LEI, Matthews, NC
 Ed Manuel, N5EM, Houston, TX
 Lou McFadin, W5DID, Orlando, FL
 Glenn Moody, N4OUL, Louisville, KY
 Chris Pezzutti, N8FWY, Pickerington, OH
 Keith Pugh, W5IU, Ft. Worth, TX
 Bob Reisenweber, W3BBO, Erie, PA
 Martha Saragovitz, Silver Spring, MD
 Jay Sattler, N8JTR, Lake Orion, MI
 Andy Skattebo, KA0SNL, Sumner, IA
 Jerry Smyth, N8ULU, Dearborn, MI
 Masaji Tamagawa, JH1AOY, Kimitsu-City, Japan
 Bill Tynan, W3XO, Kerrville, TX
 Stan Wood, WA4NFY, Orlando, FL



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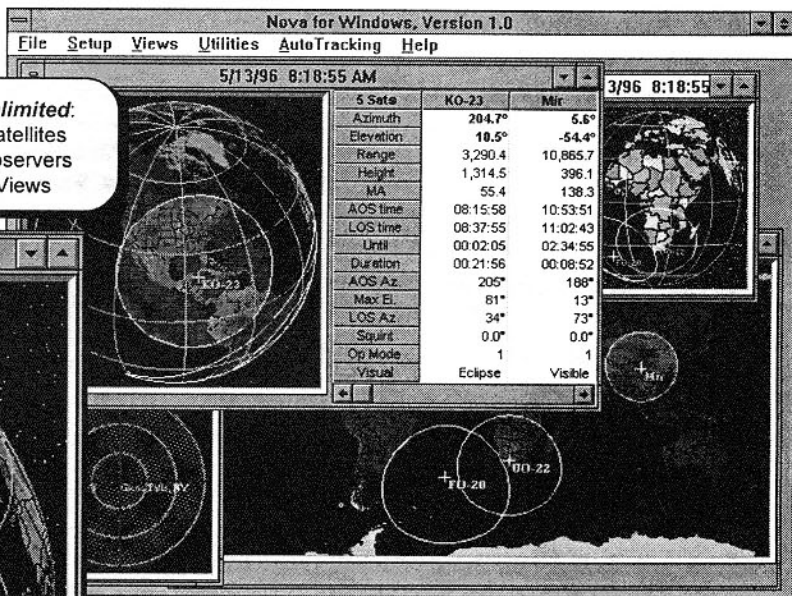
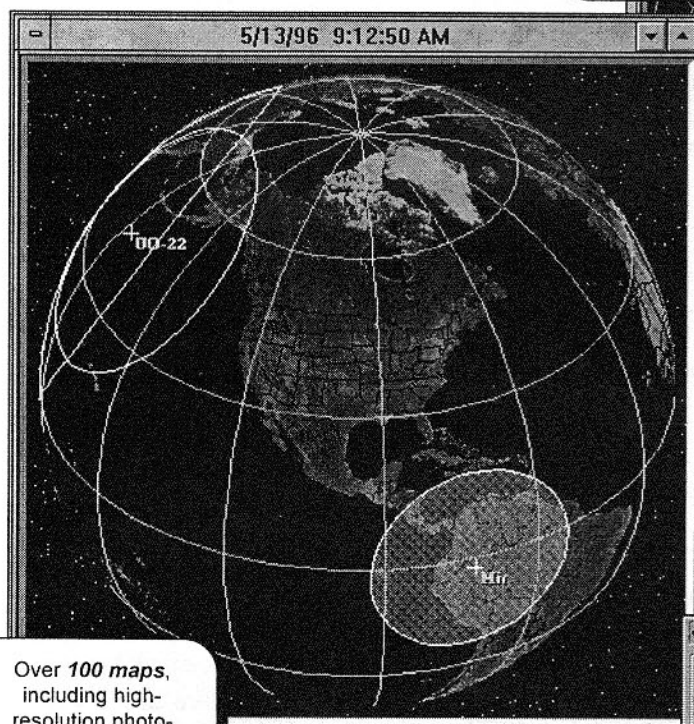
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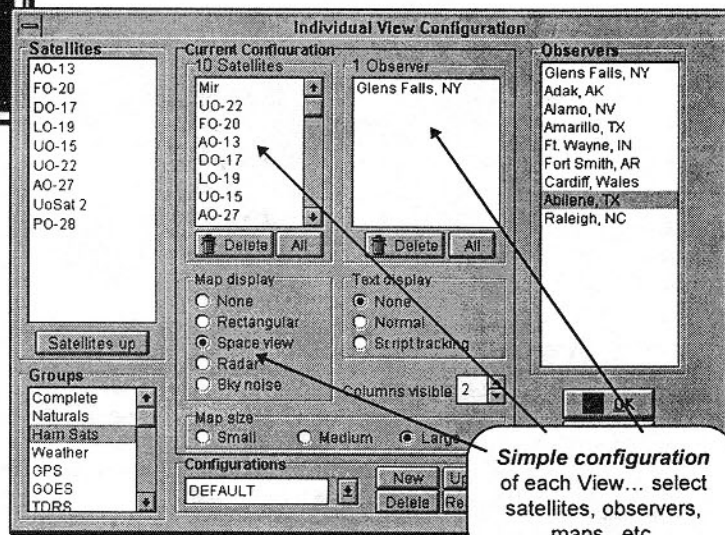
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Current Amateur Satellite Frequencies

Analog Satellites

Satellite	Beacon (MHz)	Uplink (MHz)	Downlink (MHz) ¹	Type
AO-10 ²	145.810 and 145.987 ³	435.030-435.180 LSB/CW	145.975-145.825 USB/CW	Mode B
AO-13 ²	145.812 and 145.985 ⁴	435.423-435.573 LSB/CW	145.975-145.825 USB/CW	Mode B
AO-13	2400.661 ⁴	435.603-435.639 USB/CW	2400.711-2400.749 USB/CW	Mode S
AO-27		145.850 FM	436.800 FM	Part-Time Repeater
FO-20 ⁵	435.795	145.900-146.000 SSB/CW	435.800-435.900 SSB/CW	Mode JA
JAS-2 ¹⁰	435.795	145.900-146.000 SSB/CW	435.800-435.900 SSB/CW	Mode JA
RS-10 ⁶	29.357	145.865-145.905 USB/CW	29.360-29.400	Mode A
RS-12 ⁷	29.408	21.210-21.250 USB/CW	29.410-29.450/145.910-145.950	Mode KT
RS-15	29.352	145.858-145.898 USB/CW	29.354-29.394	Mode A

Digital Satellites

Satellite ⁸	Name or Callsign	Uplink (MHz)	Downlink (MHz) ¹	Type
UO-11			145.825 FM	1200 Baud PSK
AO-16	PACSAT	145.900, .920, .940, .960 FM	437.0513 SSB	1200 Baud PSK
DO-17	DOVE		145.825 FM	1200 Baud AFSK
WO-18 ⁹	WEBERSAT		437.104 SSB	1200 Baud PSK AX.25
LO-19	LUSAT	145.840, .860, .880, .900 FM	437.1528 SSB	1200 Baud PSK AX.25
UO-22	UOSAT5	145.900, .975 FM	435.120 FM	9600 Baud FSK
KO-23	HL01	145.850, .900 FM	435.175 FM	9600 Baud FSK
KO-25	HL02	145.870 FM	436.500 FM	9600 Baud FSK
IO-26	ITMSAT	145.875, .900, .925, .950 FM	435.822 SSB	1200 Baud PSK
POSAT	POSAT1	145.975 FM	435.2777 FM	9600 Baud FSK
JAS-2 ¹⁰	8JIJCS	145.850, .870, .890, .910 FM	435.910 FM	1200 Baud BPSK

MIR and SAREX

Spacecraft	Callsign	Uplink (MHz)	Downlink (MHz) ¹	Type
Mir	ROMIR	145.550 FM	145.550 FM	Simplex Voice or Packet
Mir	ROMIR ¹¹	435.750 FM	437.950 FM	Repeater
Mir	ROMIR ¹¹	435.725 FM	437.925 FM	Voice
Mir	ROMIR ¹¹	435.775-436.775@25kHz spacing	437.975 FM	9600 Baud Packet
Shuttle	WSRRR	144.490 FM ¹²	145.550 FM	Packet
Shuttle	Various	144.910, .93, .95, .97, .99 FM ¹²	145.550 FM	Non-Mir Docking Missions
Shuttle	Various	144.450, .470 FM ¹²	145.840 FM	Mir Docking Missions

Notes:

- 1) Frequencies are shown without Doppler compensation. At start of typical LEO pass, the original signal will be several kHz higher than shown. Refer to specific satellite operating instructions for complete details.
- 2) For AO-10 and AO-13 Mode B, transmit in LSB, receive in USB. Also in Mode B, when the transmitted frequency is increased the received frequency will decrease (inverting transponder). AO-10 is no longer controllable but the transponder works when the satellite is in sunlight.
- 3) AO-10 beacon is an unmodulated carrier. Do not transmit to the satellite if the beacon is FMing.
- 4) AO-13 beacon sends CW at beginning of the hour and 30 minutes past the hour, RTTY at 67 wpm at 15 and 45 minutes past hour, and 400 bps rest of the hour.
- 5) Presently, FO-20 digital JD mode is not operational.
- 6) RS-10 Robot via 145.820 MHz uplink and 29.403 MHz downlink.
- 7) RS-12 Robot via 21.129 MHz uplink and 29.454 MHz downlink.
- 8) Digital satellites use a program suite containing PB/PG/PFHADD/PHS or WiSP.
- 9) WO-18 transmit experimental and image data and can be captured in KISS mode via PB or TLMDC.
- 10) JAS-2 Launch scheduled for August 17, 1996. For additional details, refer to JAS-2 article the Sept/Oct 1995 issue of *The AMSAT Journal*.
- 11) Tentative frequencies for SAFEXII that are currently being tested. Refer to AMSAT News Services bulletins for additional information.
- 12) These are typical SAREX uplink frequencies. Refer to AMSAT News Service bulletins for exact SAREX frequencies.

Lessons Learned Operating an AMSAT Booth

Gary B. Rogers, WA4YMZ wa4ymz@amsat.org

Like a boat show for the sailor or a fly-in for the pilot, nothing quite gets the juices flowing in an Amateur Radio operator like a hamfest. With the dealers showing their wares, constantly running seminars and all those treasures to be found in the flea market, it may seem that there is just too much to take in. As a consequence, it might be that smaller displays and booths are neglected. As an organization, AMSAT can often be found in the midst of this fray, and unless we are careful, we run the risk of being one of the slighted. What follows are the observations of a first time booth staffer, drawn from my recent experience at the Raleigh, NC, hamfest, as well as some suggestions, both personal and from other individuals, on how we can make sure that our displays are not ignored. I also want to assure those folks that have yet to volunteer to head-up or work at a booth that it is not an impossible task and can actually be very rewarding!

Before we get started, perhaps a bit of history is in order. While attending the 1995 Raleigh Amateur Radio Society Hamfest (RARSfest) I stopped by the AMSAT booth and had the pleasure of making the acquaintance of Carl Starnes, W4EAT, who had been running the booth for several years, having taken it over when his brother Sherman, W4TZU, moved to Florida. In the course of our conversation, Carl mentioned that he had driven three hours that morning to be in Raleigh in time to set up and open the AMSAT booth. I am not exactly sure what got into me but, since I lived only 15 minutes away, I said I would be happy to be in charge in 1996. He agreed, and we spoke no more of it.

It was now 11 months later, and it had occurred to me that it would soon be time to start making arrangements to do as I had promised. "Piece of cake," I thought, but I soon started to worry and, before total panic set in, I did what I had done many times before: I posted a plea for help to *amsat-bb*. To my delight, I received several very good suggestions, as well as words of encouragement and requests that I let them know how things went.

Sunday, April, 14, 1996 arrived way too early as the alarm clock went off at 4:30 am. Still a bit apprehensive about the day to

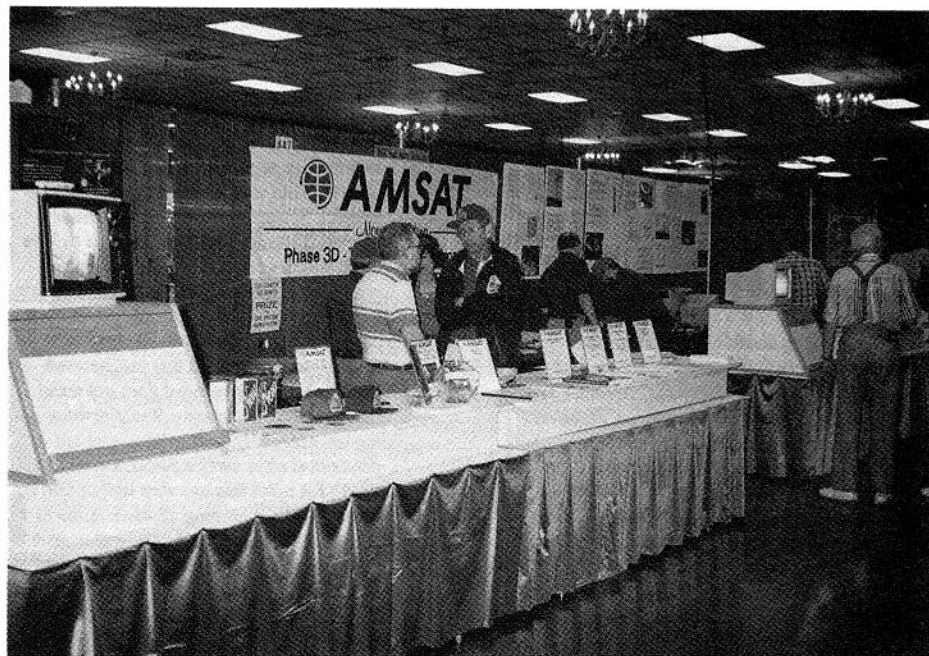
come, but determined to do the best I could, I was soon out of the house and on my way to the North Carolina State Fairgrounds, site of the RARSfest. One advantage of arriving well in advance of the general population is that you can drive right up to the door of the exhibit building to unload, which I did within just a few minutes. It was less than 20 minutes later that I realized I was finished setting up and the AMSAT booth at the 1996 RARSfest was ready to receive visitors! The rest of the day was a blur of names, faces and call signs, some known to me and some new, and all eager to talk about satellites. It was perhaps the shortest ten hours of my life!

What follows is a rather long compilation of my thoughts and ideas, derived from my *first timer* experiences, and in response to those requests by the concerned individuals who wanted to know how things went. This is actually the second revision of this document; the first drew more interesting ideas and I felt I should do a re-write to include them. Where appropriate, I have noted the name and callsign of the person or persons who made a particular suggestion. Those that came in as a response to my first roll-up that I did not actually use (this time, but wait until next year!) have been added to the end of the list. If you already work an AMSAT

booth, or if you are absolutely certain you never will, you may wish to stop now. If, however, you have considered volunteering to help or if there is not an AMSAT presence already at your local hamfest, please read on.

If you have decided to host a booth at a hamfest that has not had one, or are taking over the booth from someone else, there is a little preparatory work that must be done well in advance of the event itself. First, contact the organization that is sponsoring the hamfest to verify that someone else has not already done the same. If so, maybe that person is looking for volunteers. If not, schedule a space or booth, and do not forget to ask about the availability of tables, chairs, and electricity. At some events, space is on a limited *first come - first serve* basis so be certain you will have some place to set up before continuing.

Once you are positive that you have a space reserved, contact Martha at AMSAT HQ (martha@amsat.org) at least three weeks in advance and let her know the particulars, including who you are, the date of the hamfest, and how many people usually attend. She needs the last piece of information so she will know how much of each item to pack in the *goodie box* you will receive. This box will contain software,



Throughout North America, AMSAT-NA participates in many hamfests and conventions. WA4YMZ provides valuable information for successfully presenting AMSAT at these events. (AMSAT-NA photo by Keith Baker, KB1SF)

books, handouts, patches, and a banner for display and should arrive about one week before the hamfest.

Once you have received the materials that Martha has sent you, conduct an inventory of what was sent to you. Verify the quantity, note the *suggested donation* requested for each item, and familiarize yourself with the materials that you received. Martha provides a detailed inventory sheet, so it will be easy to confirm what was forwarded to you. Also, consider making a list of items that you will need to bring to the hamfest. Such a list might include powercords, duct tape, cashbox or container to hold cash, change, pens and paper for notes, and signs showing the suggested donation for each item and the time and location of any AMSAT forum.

These two points having been covered, it should now just be a matter of waiting for the big day, showing up, setting up, and doing your bit for the cause. (Of course, you may want to use some of the waiting time to try talking a few of your friends into helping staff the booth; you will be glad you did.) Hours later it will all be over, you will have completed your first effort of staffing an AMSAT booth, and you will be thinking "*Hey, that wasn't so bad.*"

As with any new endeavor, you will probably look back and think of a few things you will wish you had known in advance. What follows is my list, along with some suggestions for *next time*. Suggestions and ideas from other people are noted by those persons' callsigns in brackets.

- Give yourself sufficient time to set up the booth before the crowds arrive. Hamfests usually permit early entry to groups and companies that need to arrange their displays. You may have the table and chairs already on site, you may have to put them in place yourself, or you may even have to provide your own and will need to haul them to the booth area. That in itself can be a real chore, but you will also need time to unload the supply box from AMSAT HQ, assemble your computer to get whatever program you are using up and running, and hang the banner. This last item will go more smoothly if you remember to take a supply of pins, thumb tacks, small clamps, etc., so you will not be in a position of not having a means to get the banner hung. Once that is all done, take a few moments to collect your thoughts, and prepare for the time of your life!
- Once the crowds arrive, say *Hello* to everyone. If nothing else, it draws their attention

to the booth so, if they just keep walking, at least they know you are there and may stop by later after making the rounds in the flea market area.

- Although we operate the booths to represent AMSAT, most people will be interested in the satellites, not our organization, so we have to work it into the conversation in an unobtrusive way. If all folks hear is "*Join AMSAT - \$30 a year*", chances are they will just keep walking. Have the various books and aids laid out to be seen and thumbed through, then explain how inexpensive they are because we really just want to get people onto the satellites and any monies we take in are used for that purpose.
 - Do whatever is necessary to have a computer up and running one of the tracking programs [WB2LEI/KC6EIJ]. I had Instant Track going on a borrowed 386SX laptop with an outboard color VGA monitor and it drew a lot of attention. People walking by would stop to watch the screen for a few minutes, providing the perfect opportunity to say "*May I answer any questions for you about the Amateur Satellite program?*" This allowed them to *passively* make the first move if they have some interest but did not know what to ask. Another option is to run a *slide show* of images on your computer using one of the popular free-ware/shareware graphics viewer programs and pictures pulled off the Web [KC4YER]. There are several very good shots of Phase 3D under assembly available on the AMSAT ftp site.
 - Nothing tests how much you know, or think you know, better than trying to explain something to someone else. Putting concepts into words is more difficult than you may imagine. Brush up on any aspects of the hobby with which you are only a bit familiar. Here is where it really helps to have more than one person in the booth at a time, especially if you each have different operating styles and habits.
 - Expect a lot of questions on Mir and SAREX [WB2LEI]. There is nothing quite as attractive to some people as the prospect of being able to talk to an astronaut or cosmonaut. Know the schedules and modes needed. Tell them that it is possible to hear QSO's with operators in these spacecraft with their 2-meter HT or mobile if they use even a modest antenna. Some people even do this with their scanners. Be honest, though, and warn them that just because the spacecraft is overhead does not mean that there is any Amateur Radio activity going on, especially on the Shuttle which does not always carry a SAREX package. KC4YER takes this one step further and actually plays a recording of some of the Mir and SAREX contacts. He also produces a color graphic showing the current or next mission's logo, launch date, callsigns of all the licensed astronauts, modes used and frequencies. [KC4YER]
 - Know the current status of Phase 3D. This bird is getting a lot of press as the solution
- to every ham's satellite needs. Many people had the impression that they would be able to sit on their back deck and talk to folks all over the world with just their 2-meter HT and a duckie antenna. Let them know that, although things will be much easier and there will be a lot more opportunities for good DX, it will not be as easy as picking up the phone.
- Be prepared to be pleasantly surprised. I had a few people tell me that they were interested in space and became Radio Amateurs just to be able to use the satellites!
 - Be prepared to dispel the myth that operating the satellites requires lots of expensive equipment and huge antenna systems. Let them know that they may already have all they need, and that what they use on the satellites is good for terrestrial contacts as well. Ask them what equipment they have already and see if you can fit that into the requirements of one or more of the satellites. If they are not sure that they want to take the plunge, suggest they just listen to some of the downlinks to get an idea of what they can expect.
 - Many people were concerned about tracking programs and Keplerian elements. Show them what we offer, including how easy it is to update the elements. Know some sources for retrieving Keplerian element sets: AMSAT's Keplerian element mailing list, the local packet or landline bbs's, the Amateur Radio areas of CompuServe and America On Line (among others), WWW and ftp sites, etc. Provide Keplerian data sheets as handouts. These can be provided to persons purchasing tracking software from AMSAT or specifically requesting this information.
 - Some people will shy away from the cost of the software we offer. If you have not done so already, tell them about AMSAT and how all funds we raise are funneled back into the Satellite program and not into someone's pocket. I was very happy to find that this did matter to some hams, even if it meant spending a little more. Even then, some people will balk. Rather than letting a potential satellite operator walk away, do not hesitate to mention other, less expensive options, such as STSOrbit Plus. This program is really excellent and is actually available from the AMSAT ftp site, so we kind of have approval anyway.
 - Have a pad or stack of scrap paper available. This comes in handy if you need to graphically explain a concept or need to take someone's name for reference. Be sure you do not forget the pens and pencils.
 - A major purpose for operating an AMSAT booth is to help solicit memberships and encourage renewals. When obtaining memberships, make sure that the application form is legible and all the information is provided. If a personal check is used, staple it to the form. Personal checks should have the name and address pre-printed; do

not accept checks without this information. Note daytime telephone number if VISA or Master Card is used.

- Have some *change money* for the collection box, preferable \$1 and \$5 bills. Almost everyone who handed over cash had \$20's, most likely fresh from the ATM. Sometimes the difference in making a sale or not is whether you have the correct change available. Do not forget to keep tally of what money came in for each item, too, because you will need to report this and you will want to get back what you put in at the start. I used one of those inexpensive receipt books and it worked very well. When seeking donations, it does not hurt to explain that AMSAT is a registered non-profit organization so you will not be collecting sales tax and the monies you take in are kind of like donations and the items they receive are premiums. Keep in mind that we must indicate that AMSAT does not sell materials; they are provided at a *suggested donation* level. The point is that we exist to support and encourage the Amateur Radio satellite program, not to make money. [KB9BNR]
- Speaking of money, you will also need some place to keep it [W4EAT]. I used a plastic resealable storage container, but have also seen people use small tackle and tool boxes, cigar boxes, large envelopes, shoe boxes, and even jars. Whatever you use, make sure it is large enough to be able to store the money, receipts, checks, applications, and any other paperwork that you might receive. Even though carrying around a large roll of cash can be a nice experience upon occasion, avoid the temptation to keep it all in your pocket; it's just too hard to get to when needed.
- If you are not used to talking for hours on end, have a large glass of ice water available to soothe your throat. Trust me on this one; it is very important.
- Have plenty of notes for reference. It would not hurt to go ahead and purchase your own copies of the laminated Frequency Chart and *The Satellite Experimenter's Handbook*. For us, these two items went quickly and were unavailable to look up the answers to simple questions like "What are the uplink and downlink frequencies of AO-27?" This was really embarrassing at times. If you just draw a blank on a question, admit it. Take their name and tell them you will find out what they want to know and you will get back with them, then do it. They will remember how you went out of your way to help, and you will have learned something in the process.
- Advertise ahead of time. I had a few people stop in just because they saw my postings here and on the Raleigh Amateur Radio Society landline BBS. Chances are these people will not be interested in buying anything, and probably do not need any questions answered, but one advantage of the AMSAT booth is that it serves as a gathering point for satellite operators, some of whom have spoken *on the birds* many times but never met face-to-face. (While they are there, it never hurts to suggest renewing their membership, either.) You may get lucky and find a few volunteers this way, too.
- Thank everybody that stops by. As a follow-up, I had some slips printed up with my name, callsign, phone, e-mail and postal address that I handed out. These slips said, in essence, "Thanks for stopping by the AMSAT booth. If you have any questions that I might answer, please contact me." [KB9BNR] People seemed to appreciate that they could get help later if they needed it.
- Have plenty of freebies on hand, particularly the *What is AMSAT* brochure/membership form. [WD8LAQ] People really like to pick up literature and stuff it into whatever bags they may be carrying around. Later, they will have this to read and having something satellite and/or AMSAT oriented might be all they need to turn a passing curiosity into the active reality of satellite operation and AMSAT membership.
- Although you are operating an AMSAT booth, do not be afraid to give people directions to outside sources of information about the satellite program. As examples, the ARRL Mail Server provides many good text files on working the birds, practically all of the monthly periodicals have satellite columns or cover them in the VHF/UHF sections, and many Web sites have links leading to lots of information of interest to the satellite operator.
- When the hamfest is over, pack up, clean up, and leave. Go home and rest, because you will probably need it. If you are fortunate enough to have a booth provided free of charge by the hamfest sponsors, make sure you thank them, because they probably lost some revenue by giving away a space that could have gone to a dealer. While you are at it, thank your helpers, too. They worked just as hard as you did. Besides, you will want them to come back again next year, won't you?
- After you have *recovered*, you will need to conduct an inventory of the materials that remain, as well as account for the donations collected, memberships made (new and renewals), etc. Use the inventory sheet that Martha provided to complete this task. Also, please do not procrastinate on returning materials to Martha. A reasonable goal is to return materials and donations to AMSAT-NA HQ within five working days.

Other suggestions included setting up a station and trying to make a few contacts [KC6EIJ], having models of the various satellites [WB2LEI], and holding a forum on satellite operation [WB2LEI]. All are excellent ideas and I will certainly consider making them part of next year's effort.

Do not be afraid to try something on your own, either. Use your imagination. If you see an area that I have not covered that should be addressed, go for it. Remember to share it with the rest of us, too, so that we all may benefit. For example, I have produced a *first version* of a list of currently available satellite information. This six page handout was made available at the Dayton Hamfest and Martha has copies. This handout provides information on a variety of satellite publications, Internet sites, monthly columns, etc. In the future, a basic Frequently Asked Questions (FAQ) sheet may be developed for use at hamfests.

If you have stayed with me this far, let me encourage you to consider working at an AMSAT booth. It really is not hard, and the rewards are many: you get to help AMSAT, expose people to satellite operation, meet and socialize with your peers, and find out just how much you really know. It is a satisfying, enlightening experience.

I want to express my gratitude to Jerry Malin, WB2LEI, JC Smith, KC6EIJ, Pat Kilroy, WD8LAQ, and Dave Mayfield, KB9BNR, who responded to my request on the AMSAT-BB for suggestions, and to Philip Chien, KC4YER, for some additional ideas in response to my second posting. This is also a good time to say Thank You to Carl Starnes, W4EAT, who still made the three hour trip to Raleigh, although he got to sleep a little later this year. I must also thank the Raleigh Amateur Radio Society, sponsor of the hamfest where I had my *first booth experience*, for once again donating the space for the AMSAT booth, space they could have sold to a commercial vendor. RARS is my *home club*, and a nicer group of folks would be hard to find.

I hope to see you on the birds soon, and at the 1997 RARSfest! ■

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Testing Phase 3D's 10 meter Antenna

Philip Chien, KC4YER (kc4yer@amsat.org)

With 26 different antennas, six transmitting bands, and six receiving bands, Phase 3D antennas are a major task. The different transmitters and receivers can interfere with each other, and reduce the system's overall performance. For most of the antennas we can use scale models with a corresponding increase in frequency. A one-third scale model is used to test the 2 meter (VHF folded dipole) and 70 cm (UHF patch) antenna designs. To test the 2 meter antennas at one third scale a frequency three times higher is used, which is conveniently in the 70 cm. amateur band. The one-third scale 70 cm. antennas are tested at 23 cm. But scaled-down mockups of antennas and the spacecraft have their limitations. The Phase 3D integration team built a full scale aluminum mockup of the top deck of the spacecraft specifically for antenna testing, which the volunteers promptly nicknamed the parasol. It holds the full scale 2 meter

folded dipoles, 70 cm. patch antennas, 23 cm. short back fire, and parabolic dishes for the S & C bands. The antenna simulator really does work - even with actual satellite operations. We've placed the parasol on a stand in the lab's back yard and used it to make contacts through AO-10 and AO-13 (Figure 1).

This article is the story of full scale testing of the 10 meter antenna by a group of volunteers under the direction of Antenna Manager Stan Wood WA4NFY.

The 10 meter antenna is more difficult to test than the other antennas, even though it's the simplest design. It's a 2 element yagi, based on AMSAT's earliest antenna design utilizing a carpenter's retractable tape measure. The bottom of the spacecraft has the driven element which will be pointed straight back from the spacecraft's bottom surface. The director element is

attached to the top deck of the spacecraft, canted up 30 degrees. At launch the two elements will be folded underneath the four deployable hinged solar arrays. When the arrays are released the two elements will spring out to their operating positions. Stan Wood WA4NFY built a palm-size 1/15 scale model of the spacecraft to test the 10 meter antennas. At 1/15 scale the antenna works perfectly in the 70 cm band.

But recommendations from professional satellite RF engineers convinced him that it was necessary to do a full scale test, isolated from outside sources of interference. In simple terms we had to build a full scale metal-skinned mockup of the space craft and raise it 9 meters (30 ft.) in the air!

The task of converting the parasol, which

included only the top deck, into a full scale mockup of the spacecraft and building an A-frame structure to raise the mockup in the air fell to volunteers Brian McMinn N5PSS and Tom Lynch who spent a week working at the Phase 3D Lab. (Figure 2)

They used aluminum angles to build a skeleton frame in the shape of the actual spacecraft. Stiff aluminum foil-coated insulation boards were used for the sides and bottom of the spacecraft. All of the pieces had to contact each other to ensure a good ground. In addition, two load-bearing 2x4s were bolted to the top deck to attach the mockup to the lifting fixture.

Stan purchased two 1/2" x 25 foot carpenter's tape measures for the test antennas. He punched a series of holes into one end to make it easy to adjust the lengths of the elements. The tapes were purposely cut long, with the capability to shorten them in one inch increments. Conveniently the rule was already calibrated in inches which is a definite advantage when using tape measures as antennas!

In space the antennas will spring out to their full length without any sagging. Since we would be testing the antenna in a normal gravitational field we built a set of support dowels and strings to hold the two antenna elements in place.

A post-hole digger was used to bury two support posts for the pivots into the lab's back yard. The A-Frame was built from twelve 2x4s, assorted bolts, and scrap lumber.

The first challenge was taking the mockup, with the attached 10 meter prototype antenna out of the Lab without knocking over anything.

A short ladder was used as a temporary stand while we attached the spacecraft's support arms to the A-frame (Figure 3). The winch to raise the mockup to its test position consisted of a couple of pulleys, 30 meters (100 ft.) of high strength rope, and four volunteers - plus the use of Mary Wood's car as an anchor to hold it in place. There was less than a foot of clearance between the 10 meter antenna and the fence so one volunteer was positioned at the 10 meter

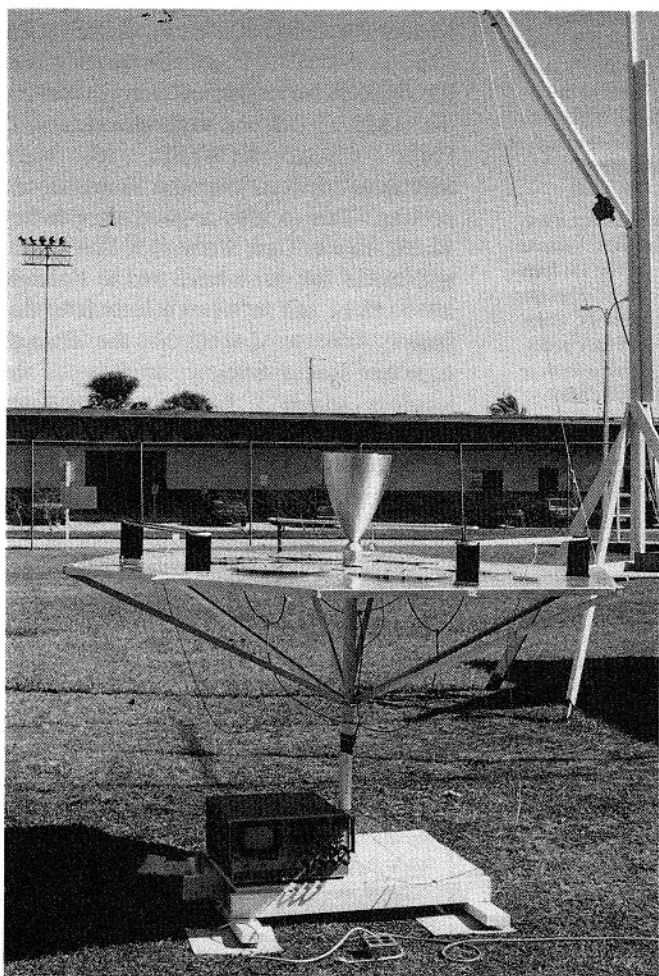


Figure 1. The 'parasol' with its 2 meter and 70 cm. antennas. The mockup 'motor' in the middle is actually a propeller spinner. (Photo by W5DID)

antenna to make sure it would not get snagged in the fence. Stan Wood and Ralf Zimmerman DL1FDT were responsible for guiding the A-Frame as it went up. The *muscle team* consisted of Bern Ludewig DH5IAE, Coy Hilton E4YHD, Roberto Pileggi, and Jeff Zerr to pull the lifting rope. Jeff Zerr was also responsible for the hoist pulley which controlled the loads on the winch assembly. Others involved in the test included: Chuck Hennessey W4AT, Frances Cozza, and Lou McFadin W5DID. (Figure 4).

Our first raise was a dry run to check out everything, and to make sure that everybody knew what to do. While the mockup weighed well under 45 kgs. (100 lbs). it had all of the volume of the entire spacecraft. At 9 meters (30 ft.) above the ground it was impressive to see how even a light breeze would cause it to wave back and forth.

We did not have a 6 meter (20 foot) RG-58 cable to go from the mockup on top of the A-Frame to an SWR meter on the ground so we connected several smaller cables together. The test cable was connected to the prototype antenna and taped to the A-frame.

Our second raise featured the first actual SWR and impedance measurements. As planned the elements were too long, so they were adjusted to the proper lengths and we raised it again.

Next we used the remaining foil-coated insulation boards and a couple of 1" x 1" wooden supports to make mockup solar panels. One of the minor problems during the day was trying to find tape measures for measurements. We kept coming across the rules which had been converted into antennas and the remaining pieces were too short to be useful! To accurately simulate the solar panels the foil was scored in the proper locations where the hinges would be located in the real panels. Pieces of aluminum foil were taped to adjacent surfaces to ensure a good conductive path between the solar arrays and the body of the spacecraft.

We are only concerned with the 10 meter performance while the solar arrays are opened. If, for some reason the solar arrays are not extended in space then the 10 meter antenna will remain in its undeployed configuration behind the solar panels. So its

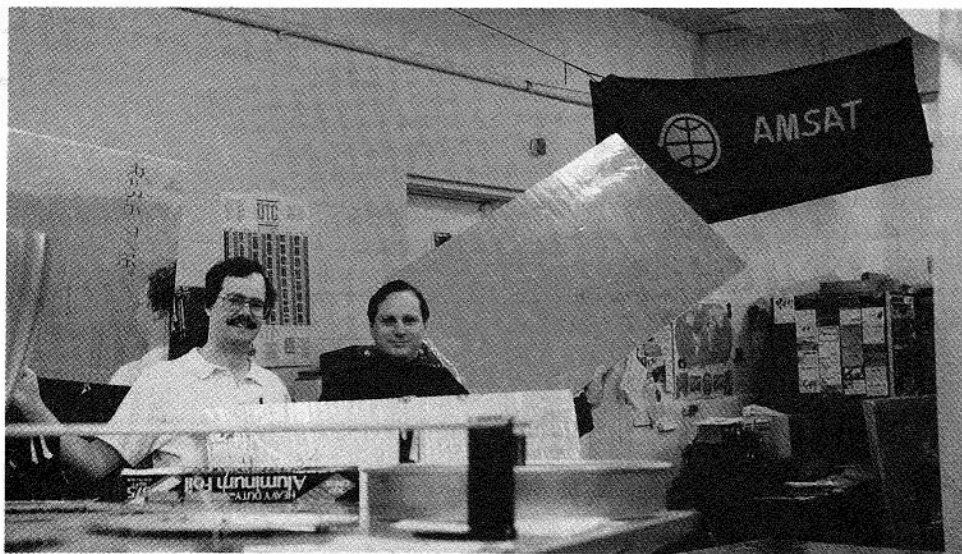


Figure 2. Brian McMinn N5PSS (L) and Tom Lynch (R) hold up foil coated insulation panels which they will use to convert the parasol (foreground) into the full-scale mockup of the Phase 3D project. Note the box of aluminum foil. (Photo by W5DID)

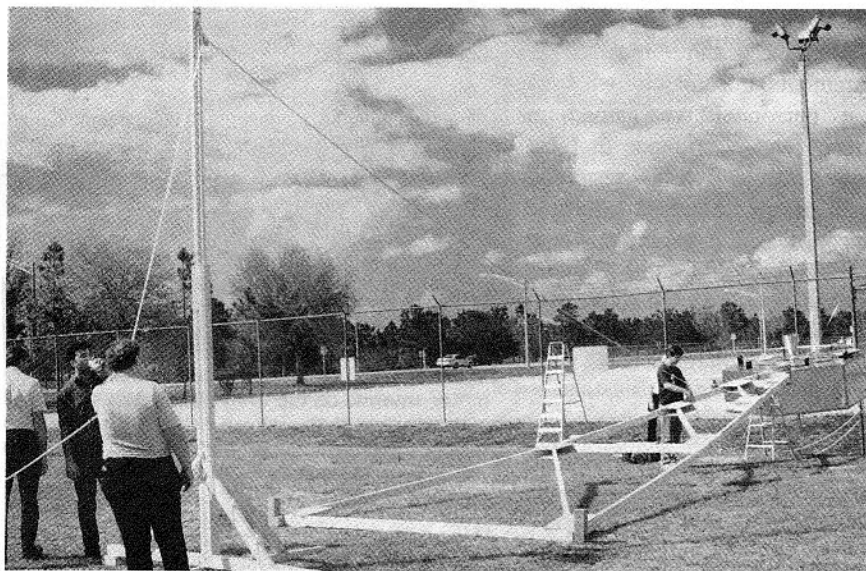


Figure 3. Jeff Zerr attaches the lifting rope to the A-Frame. Note the Phase 3D mockup attached to the A-Frame. (Photo by KC4YER)

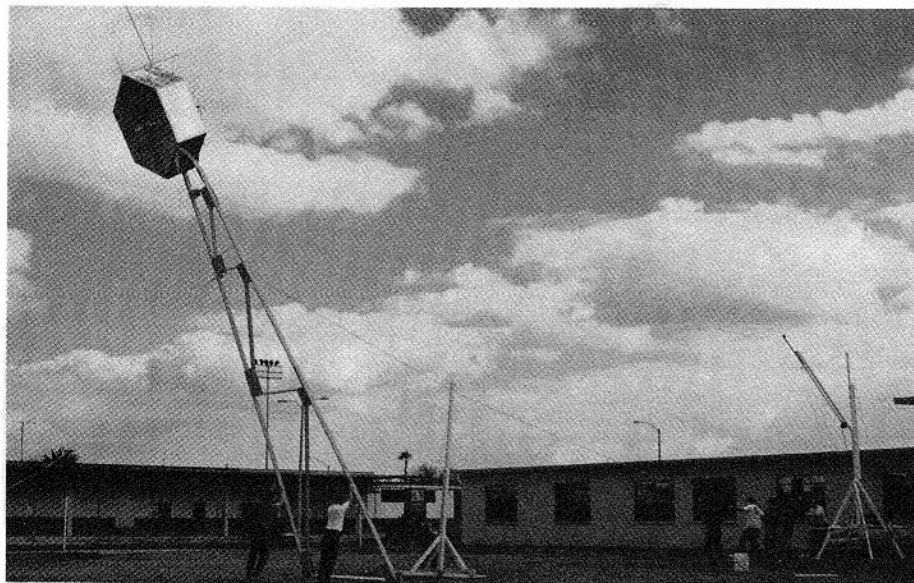


Figure 4. The first attempt to raise the Phase 3D mockup. Five volunteers are hauling on the rope while Stan and Ralf guide the A-Frame. (Photo by KC4YER)

SWR won't matter because it won't be usable.

After we had raised the mockup with the solar panels to its test position above the ground we all were amazed at how closely it resembled the real satellite - at least from a distance. Even on the ground it's incredibly impressive. You can't help but appreciate the size of the Phase 3D spacecraft when you're standing next to a full-sized mockup with open solar arrays! (Figures 5 & 6)

As anticipated, the open solar arrays did change the SWR slightly which we were able to easily compensate for. Unfortunately, as we went through the various tests some of the volunteers had to leave, and we had fewer and fewer people to raise the A-Frame and make the measurements. Fortunately, what we lost in personnel we gained in experience and confidence that the A-Frame would work properly. Several people handled multiple responsibilities. For example, I was responsible for holding the 10 meter antenna as it was raised to keep it away from the fence, and once it was clear I could take photos.

At one point I lay down on the ground underneath the A-Frame to



Figure 5. The Phase 3D mockup with the solar arrays and 10 meter antenna on top of the A-Frame. Stan Wood WA4NFY stands next to the left leg of the A-Frame examining the antenna's performance on an SWR meter. (Photo by KC4YER)

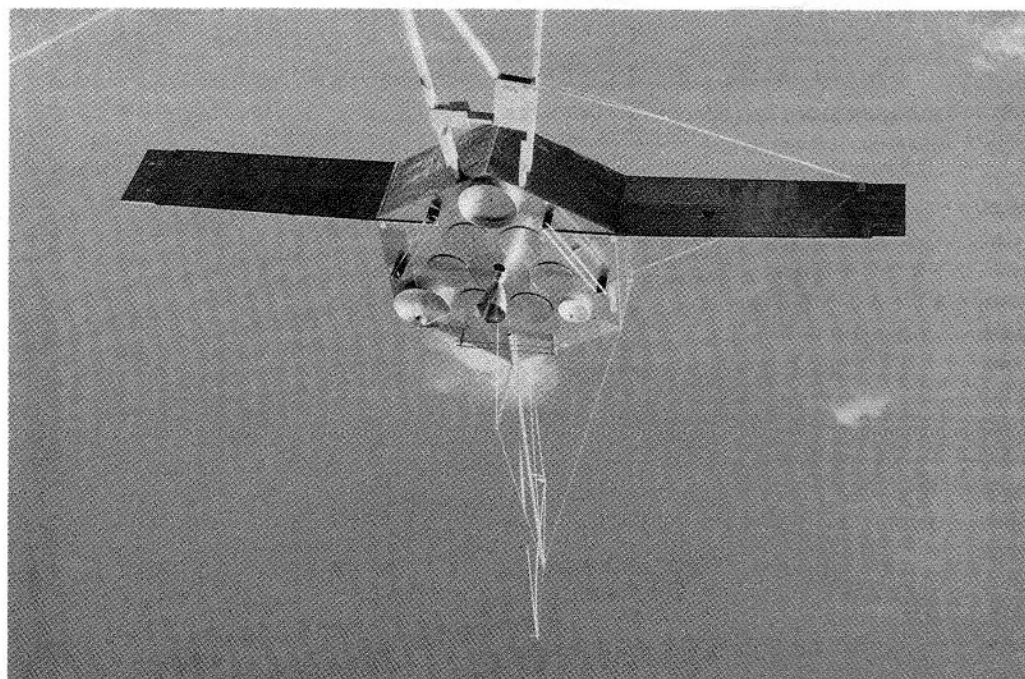


Figure 6. The Phase 3D full scale mockup with extended solar panels and the mockup 10 meter antennas. (Photo by KC4YER)

take photos of the mockup as it was lowered on top of me. I had full trust that Stan and Ralf considered me valuable enough not to drop the entire apparatus on top of me! Well, my trust wasn't misplaced. As they gently lowered the mockup, Stan gave me plenty of warning and I rolled out of the way with plenty of room to spare.

The day's measurements resulted in a driven element of 2.7 m. (106.5 inches) and a director of 2.12 m. (83.5 inches) at 29.4 MHz. The impedance was near 50 ohms and the SWR was 1.1:1. Computer modeling predicts a gain of 2.75 dBi.

After we were all confident that we were getting good data Stan wanted to try one final test. What if the 6 meters (20 ft.) of cable with several connectors changed the SWR? Any test now would give us more confidence and certainly be easier than after the satellite's launch! So we did one final test. We duct-taped the SWR meter to the side of the mockup, connecting it directly to the antenna. Lou got his binoculars and Bern got his camera with its telephoto lens. So we raised the mockup once again and took turns looking through the binoculars to try to read the meter, with some folks even standing on a ladder while using the binoculars. We all agreed that the SWR needle was still indicating an excellent ratio, which will hopefully be confirmed if Bern's telephoto photo comes out!

During the repeated raising and lowering of the mockup several passing cars slowed down, wondering what was happening. If anybody landing at Orlando International Airport happened to be looking toward the Lab, or somebody in the control tower was looking in our direction they would certainly wonder what we were doing.

Appropriately as we lowered the mockup for the final time we lost our light. It was an exhausting but extremely productive day. ■

Minutes of the Mars Relay Flight Test Workshop

John L. Callas, Jet Propulsion Laboratory, Pasadena, California

Editor's Note: The Mars Relay Flight Test will be a two-way test of the Mars Relay on board the Mars Global Surveyor and Russian Mars '96 spacecraft. The test is planned to occur shortly after spacecraft launch while each spacecraft is near the Earth. The Flight Test will involve the support of the UHF-capable worldwide radio amateur community. A summary of the workshop held on June 7, 1996 at the Jet Propulsion Laboratory (JPL) in Pasadena, CA is presented here:

Introduction and Workshop Information

Dr. John L. Callas opened the Mars Relay Flight Test Workshop and welcomed the participants. In attendance were 27 outside (non-JPL) participants and approximately 15 JPL staff. Most of the attendees are radio amateurs. Two of the visitors were from outside the United States; one from Canada and one from France. The French visitor was André Ribes of the Centre National d'Etudes Spatiales (CNES), the French Space Agency. André Ribes is the CNES chief RF engineer who developed the Mars Relay. CNES provided the Mars Relay system to the NASA and the Russian Mars Programs.

Mars Exploration Educational & Public Outreach

Dr. Cheick M. Diarra of the JPL Mars Exploration Education and Public Outreach Office spoke briefly on the efforts of his office. He summarized some of the activities and products being generated by his office. These include efforts to distribute Mars spacecraft data (images, etc.) over the Internet as the data are received at JPL, and the development of special educational tools to permit students at various grade levels to interact with the data and produce their own scientific results. Other activities include production of information sheets, CD-ROMs, and presentation materials. The principal thrust of his office is to more meaningfully involve students and the public in the exploration of space, particularly Mars. Therefore, it was appropriate for the radio amateurs to learn of these activities since the Mars Relay Flight Test does have a significant public outreach component in itself. Those interested in learning more about JPL, Space Exploration and Mars Exploration, and Public Outreach efforts, can access the JPL Homepage on the Internet at <http://www.jpl.nasa.gov/>. From there one can navigate to each of the JPL Project Homepages.

Mars Exploration Program

Glenn E. Cunningham, WA6TPT, Project Manager of the Mars Global Surveyor Project and the Mars Surveyor Operations Project, gave a presentation on Mars Exploration. Mr. Cunningham briefly summarized previous missions to Mars by both the United States and Russia. From 1960 to 1992 there have been 26 missions to Mars from both nations. The first successful mission was the JPL Mariner 4 Mission launched in 1964. Since that time NASA has launched a total of 8 successful missions. The last US mission to Mars was Mars Observer launched in 1992. Contact with Mars Observer was lost just 3 days prior to arrival at Mars in 1993 August.

Since Mars Observer, NASA and JPL have been developing an ambitious, low-cost program to return to Mars. This program will be a decade long exploration of Mars with two spacecraft launches to

Mars every opportunity (about every 25 months). The first missions will be the Mars Global Surveyor Mission to be launched in 1996 November and the Mars Pathfinder to be launched in 1996 December. The total funding for the entire Mars Program is less than \$200 million per year. This funding must cover the cost of developing and launching two spacecraft every two years and operating all active spacecraft at or enroute to Mars over the duration of their mission. After the completion of the series of orbiters and landers, a Mars sample return mission is being considered for launch around the year 2005.

Mr. Cunningham reminded the audience that Mars Global Surveyor (MGS) uses many frequencies on board the spacecraft. There are the X-band frequencies (around 8 GHz) used for the primary spacecraft communication with the Deep Space Network (DSN) to send commands to the spacecraft, return telemetry from the spacecraft, and to provide navigation and tracking of the spacecraft. There is a Ka-band (approximately 32 GHz) experiment on board MGS to test this band for future deep-space telecommunications use. And finally, there is the UHF Mars Relay to be used for relay operations at Mars between MGS and small stations and landers placed on the surface of Mars.

Mars Global Surveyor Science

Dr. John L. Callas discussed the individual science instruments on Mars Global Surveyor. Each instrument is fixed to the spacecraft body. With the exception of the two Magnetometers (MAG) and the Ultrastable Oscillator (USO) all others are mounted on the nadir panel of the spacecraft. The nadir panel is that side of the spacecraft which is held fixed toward Mars as the spacecraft rotates about the planet.

The camera, referred to as the MOC, consists of two camera systems, a wide angle camera and a narrow angle camera. Using a linear charge coupled device (CCD), each camera collects an image as a long strip in a push broom fashion. The wide angle camera will provide two-color (red and blue) horizon to horizon, global coverage of the planet each day. The narrow angle camera will provide selected high resolution images of the surface with a resolution of approximately 1.4 meters per pixel.

The Thermal Emission Spectrometer (TES) is a multi-wavelength infrared remote sensing instrument. It incorporates a Michelson interferometer that collects infrared spectra of the surface and atmosphere. From these measurements, the mineralogical composition of the surface can be mapped globally to a ground resolution of about 2 kilometers. With limb (horizon) and nadir scans, the atmospheric structure (temperature, pressure, etc.) of Mars can be investigated continuously. Additionally, the seasonal advance and retreat of polar caps can be monitored.

The laser altimeter, referred to as the MOLA, collects altitude measurements ten times per second as the spacecraft orbits the planet. By firing a semiconductor laser towards the surface and measure the time of flight of the backscattered light, the spacecraft altitude can be measured to a precision of about 2 meters. When combined with spacecraft tracking, a global topographic map of Mars can be obtained with a vertical resolution of about 30 meters.

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The Electron Reflectometer (ER) along with the MAG will search for an internally generated magnetic field, or possibly a remnant or crustal field, at Mars. The presence or absence of a field provides insight as to the internal structure of the planet and the planet's origin.

The USO is used as a frequency reference for the X-band communication system. The radio signal from the spacecraft is accurately monitored from the ground. As the spacecraft orbits the planet, changes in the radio signal strength and frequency reveal characteristics of the Martian atmosphere and gravity field.

Mars Relay Flight Test Description

Dr. John L. Callas gave background on the use of the Mars Relay, a detailed description of the Mars Relay subsystem and operational use at Mars, and a detailed explanation of the current design of the Mars Relay Flight Test. (A detailed set of viewgraphs covering these subjects is contained in the Mars Relay Flight Test Workshop briefing package.) The objective of the Mars Relay Flight Test is to verify, while en route to Mars, the two-way functionality of the Mars Relay on board the NASA Mars Global Surveyor and Russian Mars '96 spacecraft. The approach is to enlist

the UHF-capable assistance of the worldwide Radio Amateur Community in carrying out this Flight Test of the Mars Relay shortly after launch.

The Mars Relay is a UHF transponder designed to provide a communication link between MGS and landers placed on Mars by other missions. Designed and built by CNES, the French Space Agency, and provided to NASA, the Mars Relay uses a 1.3 watt beacon at 437.1 MHz to alert ground stations that the spacecraft is within view, and two receive frequencies at 401.5 and 405.6 MHz to collect ground telemetry at either 8 kilobits or 128 kilobits per second. The Relay uses the memory of the MGS camera to buffer the received Mars surface station data into the MGS telemetry system for playback to Earth.

Detection of the Mars Relay Beacon has been tried before. Earth-based detection of the Mars [Balloon] Relay was attempted during the search for Mars Observer after contact was lost with the spacecraft in 1993 August. Several large antenna facilities around the world supported a search. Unfortunately after several attempts over many months, no signal from Mars Observer was ever detected.

Mars Global Surveyor will launch in 1996 November carrying a new CNES Mars Relay. To

assure proper post-launch functionality of the Relay, a two-way flight test is being planned. The specific objectives of the test are to:

- Verify the Mars Relay operational modes by observing at Earth the Beacon subcarriers, designated RC1, RC2, RC3 and TC;
- Confirm the far-field antenna pattern with Earth-based measurement of the beacon signal strength as a function of spacecraft rotation;
- Verify the Mars Relay receiver functionality with a radiated simulated, Earth-based Small Station signal with subsequent observation of the Relay TC signal lock-up, and a measurement of bit error rate as a function of signal level.

The Mars Relay Flight Test is currently being scheduled for Mars Global Surveyor approximately 20 days after launch, and possibly with the Russian Mars '96 spacecraft sometime soon after the test with MGS. At 20 days after launch, MGS is approximately 6 million kilometers distant from Earth. At these distances the 1.3 watt, 437.1 MHz Beacon signal from the Mars Relay is of sufficient signal level for detection

Satellite Orbital Elements

Ray Hoad, W5QGD

Satellite	AO-10	UO-11	RS-10/11	AO-13	FO-20	RS-12/13	RS-15
Catalog Number	14129	14781	18129	19216	20480	21089	23439
Epoch Time	96178.18336377	96179.00640897	96178.96619109	96178.71742334	96179.05331281	96179.08938543	96179.03236235
Element Set	431	905	235	227	887	912	154
Inclination	26.1433	97.8006	82.9252	57.2197	99.0256	82.9229	64.8194
RA of Node	202.7922	169.2925	141.3109	108.394	202.0355	181.9981	7.1618
Eccentricity	0.6011593	0.0012911	0.0012466	0.7429069	0.0541153	0.0027973	0.0160678
Arg of Perigee	26.8603	60.9955	121.011	43.2906	102.1184	203.9813	197.4358
Mean Anomaly	354.6276	299.2542	239.2269	355.1799	264.1043	156.0041	162.1008
Mean Motion	2.05880481	14.69461157	13.72366879	2.09872593	12.83233705	13.74070847	11.27526898
Decay Rate	0.00000099	0.00000076	0.00000049	0.00001723	-0.00000038	0	-0.00000039
Epoch Rev	9802	65909	45151	6153	29915	27039	6189
Satellite	UO-14	AO-16	DO-17	WO-18	FO-19	UO-22	KO-23
Catalog Number	20437	20439	20440	20441	20442	21575	22077
Epoch Time	96179.05614913	96178.73368743	96178.75498332	96178.74503690	96179.14647421	96179.04819975	
Element Set	217	992	995	9	994	704	605
Inclination	98.5436	98.5576	98.5609	98.5603	98.5623	98.3496	66.0765
RA of Node	261.8874	263.8073	264.4738	264.4024	264.895	245.2351	168.8103
Eccentricity	0.0010879	0.0010828	0.0010897	0.0011612	0.0011961	0.0006742	0.0013513
Arg of Perigee	169.7727	171.9557	170.8207	171.371	170.5585	237.6072	295.9309
Mean Anomaly	190.3674	188.1799	189.3175	188.7671	189.5828	122.4462	64.0308
Mean Motion	14.29924389	14.29978215	14.30120091	14.30089527	14.30198414	14.37027678	12.86297237
Decay Rate	0.00000011	0.00000018	0.00000016	0.00000005	0.00000011	-0.00000011	-0.00000037
Epoch Rev	33546	33543	33546	33546	33548	25949	18207
Satellite	AO-27	JO-26	KO-25	MIR	HUBBLE	Phase 3D (591)	Phase 3D (4)
Catalog Number	22825	22826	22828	16609	20580	99934	99934
Epoch Time	96179.09827059	96179.09383300	96179.14269040	96179.08737985	96179.09264427	96260.25523447	96260.25679106
Element Set	485	494	465	572	901	3	4
Inclination	98.5807	98.5798	98.576	51.6494	28.4683	60.0203	59.9968
RA of Node	254.4695	254.6318	254.7346	74.1356	154.8803	342.7876	346.4301
Eccentricity	0.0007954	0.0008386	0.0009412	0.0005342	0.0005888	0.6752895	0.6740242
Arg of Perigee	199.6894	200.6563	185.269	115.6645	277.8799	180.1221	180.0725
Mean Anomaly	160.3979	159.4284	174.8395	244.4899	82.112	179.5089	179.7634
Mean Motion	14.27698288	14.27806409	14.28144224	15.58262621	14.91068143	1.51063968	1.52667827
Decay Rate	0.00000024	-0.00000008	-0.00000003	0.00001257	0.00000258	0.00002	0.00001454
Epoch Rev	14340	14341	11153	59154	14006	2	2

by radio amateurs with large antenna systems (gain >21 dBi).

The Mars Relay Flight Test will have three parts. The first part will be to activate the Mars Relay in the Beacon CW mode. This mode broadcasts the 1.3 W Beacon as a pure tone at exactly 437.1 MHz. This will maximize the amount of power in a single [carrier] frequency. The mode will be active for a period of at least 24 hours. While enroute to Mars, the MGS spacecraft rotates about its X-axis once every 100 minutes. Furthermore, the X-axis is pointed off the Earth by approximately 30 degrees. The combination of these two effects is to produce a Beacon signal that modulates in strength with the spacecraft rotation. This feature provides an opportunity to observe different parts of the Relay's antenna pattern as the spacecraft rotates. The peak gain for the Mars Relay antenna on MGS is about 2 dBi.

After completion of this part of the test, the second part will be to activate different modes of the Relay. Each mode will be active for at least 100 minutes to allow the spacecraft to complete one full rotation. With the activation of these modes the Relay signal will drop by several dB as the Beacon is frequency modulated (FM) with one of four subcarriers. Only those radio operators with the largest antennas will be able to detect these signals from MGS. The Russian Mars'96 spacecraft Mars Relay has an antenna with 12 dBi of gain, making the signal from Mars'96 more easily detectable by radio amateurs with smaller antennas, even during this phase of the test.

The third part of the Mars Relay Flight Test will be an active uplink from the 46 meter antenna at Stanford University. The Stanford antenna will be instrumented with equipment to simulate a signal from a Mars lander. The signal will be radiated with sufficient power (~2.5 kW) to match the expected signal levels received from landers on Mars by the Relay. The radiated signal will contain a pseudo-random number (PN) sequence as the transmitted data. This data can then be analyzed to determine bit error rate (BER) after the received data is returned to Earth, via the spacecraft's X-band downlink to the DSN in the case of MGS, or via the Russian ground stations in the case of Mars'96. Additionally, those radio operators with large antennas will be able to observe the TC subcarrier modulation in the Beacon signifying the Relay receiver lock-up on the radiate signal from Stanford.

The Flight Test will be coordinated from JPL. JPL will control the operation of the MGS spacecraft and will provide instruction to Stanford for the operation of the uplink. JPL will coordinate with the Russians as to the operation of the Russian Mars'96 spacecraft. JPL will generate and distribute the position (range, RA and DEC) and Doppler shifts and Doppler rates for the MGS spacecraft. This same information will be asked of the Russians in support of testing with Mars'96. JPL will serve as the collection site for observations provided by radio amateurs around the World. The received Mars Relay telemetry from MGS will be analyzed at JPL and at CNES in France. The Relay data collected aboard the Russian Mars'96 spacecraft will likely be analyzed by the Russians and CNES.

Several sites with large antennas are currently planning on supporting these tests. Stanford University's 46 meter antenna will be the only site radiating a signal to the Mars Relay on either spacecraft. Simultaneously Stanford will also be receiving the downlink signals from the Mars Relay. The Apple Valley (CA) Science and Technology Center is working with JPL to re-instrument the

Goldstone 34 meter standard antenna (DSS-12) to receive the Relay signals. The Algonquin 46 meter antenna in Canada with help from radio amateurs is also planning to support the Relay tests.

Frequency Allocations & Spectrum Management

Paul E. Robbins, of the Spectrum Management Group at JPL, discussed the issues associated with spectrum management and frequency allocation. JPL has made an official request for allocation of spectrum to conduct the Mars Relay Flight Test to the National Telecommunications & Information Administration (NTIA). The NTIA is the U. S. Government agency responsible for spectrum management of government frequencies. The NTIA has received the request and has asked the user community for comment on the request. Some of the frequencies to be used during the test fall within bands that have user activity. Members of the user community in Southern California have been made aware of this test and are supportive. Final approval from the NTIA to proceed with the Mars Relay Flight Test is expected later this year prior to the launch of MGS.

Radio Amateur Activities

Professor Michael Owen, W9IP of St. Lawrence University in Canton, New York discussed various radio amateur activities supporting the Mars Relay Flight Test. The most likely radio amateur activity will utilize the Algonquin 46 meter (150 foot) antenna facility in Canada. Professor Owen is working with the facility operators and the amateur community to support the tests. Several other radio amateurs across the continent have large UHF antenna configurations capable of also supporting the Relay tests.

Professor Owen discussed the type of equipment necessary to detect the Mars Relay signals. A large antenna configuration tuned for 437.1 MHz is required. The signals transmitted (and received) by the Mars Relay are right-hand circular polarized (RCP). Antennas can either be right circular polarized, or even linearly polarized if the system can tolerate a 3 dB polarization loss. A series of connected crossed Yagi antennas is one possibility. A configuration of four 15-element crossed yagi antennas can achieve 21.5 dBi of gain at 437.1 MHz. To minimize noise and maximize the signal, a preamp connected close to the antenna is required. Commercial high electron mobility pseudomorphic transistor (HEMPT) low noise amplifiers (LNA) are available at reasonable costs (~\$100). These LNAs achieve high gain and system noise temperatures as low as 85 Kelvin. After the preamp the signal can be mixed and filtered down to audio baseband.

Consideration should be given to Doppler effects associated with the relative motion of the spacecraft and the rotation of the Earth when choosing the mixer local oscillator (LO) frequency and the baseband width.

Many multimedia home computers or computers with audio processing cards can digitize audio signals to 16 bits with sampling rates of 44 kilosample per second per channel. This permits the digitization of baseband to as much as 22 kHz. Digital Signal Processing (DSP) software has been developed to perform Fast Fourier Transforms (FFT) on the digitized data for spectral analysis. Some of this software is available commercially.

Tracking of the spacecraft across the sky is an important issue. Professor Owen has made available shareware software that will assist amateurs in

tracking the MGS and Mars'96 spacecraft on any given day for any amateur location. The software calculates the local azimuth and elevation settings for the spacecraft current position. For antennas with gains of 21.5 dBi the half-power beamwidth (HPBW) is roughly 15 degrees. Therefore continuous (active) pointing of the antenna is not necessary. Periodic repositioning may be sufficient to track the spacecraft across the sky.

Stanford's Mars Relay Flight Test Effort

Dr. Ivan Linscott of the Stanford Center for Radar Astronomy presented a description of the Stanford 46 meter (150 foot) antenna facility. The Stanford facility has been used to support a number of research efforts over its years of operation. It has been a valuable astronomical research tool, probing the Galactic and intergalactic regions at multiple wavelengths. It has also conducted searches for several missing or disabled spacecraft, in addition to its effort to locate Mars Observer, with extremely fine sensitivity. The facility also contains a 30 kW UHF transmitter and feed system. This transmitter will be employed to perform the active portion of the Mars Relay Flight Test, the radiated uplink of a simulated lander signal.

In addition to the hardware assets of the Stanford facility, the Center for Radar Astronomy has developed and employed several analytical tools for extracting weak and varying signals from a significant noise background. Such techniques may permit the identification of a signal, such as the Mars Relay Beacon, several octaves below the background level. With the availability of commercial analysis software and powerful home computers, it is reasonable to consider applying these analytical tools to the digitized data collected by amateurs on their UHF equipment. Additional RF equipment will be required to digitize a complex waveform. However, many multimedia computers have two audio channels (left and right) to digitize the I and Q signals associated with a complex waveform. This possibility of complex signal analysis represents an enabling technology for weak signal detection by radio amateurs in general.

Open Discussions and Conclusions

The proximity of the spacecraft to Earth shortly after launch represents an opportunity to ask the UHF radio amateur community to participate and assist in the Mars Relay Flight Test. The expected signal levels are within the reach of amateurs operating antenna systems with 21.5 dBi of gain when listening for Mars Global Surveyor or an antenna as small as 10 dBi of gain when listening for the Russian Mars'96 Mars Relay signal due to its Relay's higher antenna gain (12 dBi).

The development of advanced analytical tools, like those from Stanford University's Center for Radar Astronomy, greatly enhances the ability for amateurs to detect very weak signals, if such tools can be successfully implemented for digitized signals by individual amateurs on their own equipment.

JPL will continue to work with the radio amateur community to help realize the developments in support of the Mars Relay Flight Test. Continually updated information on the Mars Relay Flight Test can be found on the MGS Homepage at <http://mgs-www.jpl.nasa.gov/>. The JPL Open House was held on the following two days, Saturday and Sunday. Many of the Workshop participants attended the Open House. ■

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Enjoy cross band full duplex operation! The IC-821H is really two separate receivers within one compact case. Use the independent controls for each band. Both main and sub receivers have independent

Satellite operation has never been so easy or so advanced! ICOM's taken the best features from the IC-821H's acclaimed predecessor, the IC-820H, applied

RF attenuators, noise blankers, IF shift circuits, and optional CW filters. Each band also has its own S-Meter, Squelch, volume control, and independent mode selection.

Continuous Adjustable Transmit Power

Better than just using a high/low setting, the continuous adjustable Tx power feature is satellite "friendly". You'll get precise power control, and you'll help extend the life of amateur radio satellites by running the minimum power necessary.

9600 Baud Plug and Play

The same great 9600 baud packet operation featuring the modulation circuit found in the IC-820H is still here! It's the only rig *QST* magazine found to have efficient packet operation for both transmitting and receiving at 9600 baud. ICOM's famous CL-V computer interface is included.

Experience the Next Generation IC-821H for yourself soon at your local ICOM dealer. See how the best only get better.

Other IC-821H Features:

- Compact and Lightweight
- All Modes (FM, SSB, CW)
- Multi-function Scanning
- ± 3 ppm High-Stability Crystal (± 0.5 ppm optional)
- Maximum Tx Power: VHF: 45 W (FM, CW)/35 W (SSB)
UHF: 40 W (FM, CW)/30 W (SSB)
- 160 Memory Channels (60 more than the IC-820H)
- Built-in Electronic Keyer
- One-touch Doppler Shift Adjustment
- Frequency Spot Function (beeps when a programmed frequency is crossed)
- Stereo Headphone Jack & 2 External Speaker Jacks
- Mic Included
- CTCSS Encoder



NOW AVAILABLE! See your ICOM dealer today!

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